PERIODICAL ROOM
GENERAL LIBRARY
UNIV. OF MICH.

APR 26 1929

THE MAY SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

ISOSTASY AND GEOLOGICAL THOUGHT. DR. WILLIAM BOWIE ... 385

QUALITY IN GRAPES. PROFESSOR FREDERICK T. BIOLETTI ... 393

LAMPREYS AND THEIR WAYS. PROFESSOR SIMON HENRY GAGE 401

SOME OF THE SCIENTIFIC PROBLEMS OF TANNING. PROFESSOR GEORGE D. MCLAUGHLIN and DR. JOHN H. HIGHBERGER ... 417

FALLING WATER. PROFESSOR O. D. VON ENGELN ... 422

THE RÔLE OF RELIGION IN A SECULAR AGE. PROFESSOR HARRY ELMER BARNES ... 430

EVOLUTION AND RELIGION. AUSTIN H. CLARK ... 446

PERSONALLY CONDUCTED. PROFESSOR NEVIN M. FENNEMAN ... 451

PROGRESS. WILSON D. WALLIS ... 454

THE KING OF MUSICAL INSTRUMENTS. PROFESSOR ARLAND D. WEEKS ... 457

CORN-STALKS AND COBS IN INDUSTRY. L. K. ARNOLD ... 463

THE PROGRESS OF SCIENCE:

Fifty Years of the United States Geological Survey; Presentation of the John Fritz Gold Medal to President Hoover; The New Agricultural Building at Washington; Professor Einstein's Manuscript 471

THE SCIENCE PRESS

LANCASTER, PA.—GRAND CENTRAL TERMINAL, N. Y. CITY—GARRISON, N. Y.

Yearly Subscription $5.00 Single Copies 50 cents

RECENT BOOKS OF SCIENTIFIC INTEREST

An Historical Introduction to Modern Psychology. GARDNER MURPHY. With an introduction by H. KLÜVER. 455 pp. $6.00. Harcourt, Brace & Company.

An account of psychological history from the 17th to the 19th century. It presents an historical approach to that contemporary psychology which arose as a result of the interaction of physiology, psychiatry, the theory of evolution, the social and physical sciences and the progress in statistical methods.

New Practical Physics. NEWTON H. BLACK and HARVEY N. DAVIS. 633 pp. Illustrated. $1.68. Macmillan Company.

Throughout this book the practical applications of the fundamental physical principles to daily life have been stressed. Concise summaries are appended to each chapter, and questions and problems suggested to the student. This is a revised edition of the former "Practical Physics."

Textbook of Evolution and Genetics. ARTHUR W. LINDSEY. 443 pp. Illustrated. $3.00. Macmillan Company.

This volume is for students who desire a sound introduction to the subject. An account of the fundamental principles of genetics is presented in it, together with a summary of the theoretical matter and an analysis of the factors bearing upon evolutionary theory.

The Desert Road to Turkestan. OWEN LATTIMORE. 360 pp. Illustrated. $4.00. Little, Brown & Company.

A narrative of the adventures of a 1600 mile camel caravan through Mongolia to Turkestan by a previously unknown route. In the first chapters the history and present conditions of the caravan trade in Mongolia are sketched.

Experience and Nature. JOHN DEWEY. 437 pp. $3.00. W. W. Norton & Company.

This is a new edition of the work in which Dr. Dewey sets forth his philosophy. He demonstrates that philosophy is a generalized theory of criticism, and that, to arrive at more effective criticism of current values the traditional separation of nature and experience should be replaced by the idea of continuity.

Hegel's Science of Logic. Translated by W. H. JOHNSTON and L. G. STRUTHERS. Introductory preface by VISCOUNT HALDANE OF CLOAN. In two volumes. 404 pp. + 486 pp. $10.00 per set. Macmillan Company.

This is the first complete English translation of Hegel's "Science of Logic." The translation is made from the fourth edition of the *Wissenschaft der Logik*, issued in 1923 by Dr. Georg Lasson, of Berlin. The two main parts of the book are headed "Objective Logic" and "Subjective Logic."

Viscount Haldane says, in his preface to the book, "Hegel's investigation of the forms of thought is so thorough and is carried into detail with such care and illuminating illustration that it is not safe to neglect it. . . Hegel is difficult to read for those who have not first of all mastered the conception of the critical philosophy."

Physician and Patient. Edited by L. Eugene Emerson. 244 pp. $2.50. Harvard University Press.

This book is intended for all who are interested in medicine, physicians, nurses, students and all who have ever been sick, ever will be sick, or have anything to do with the sick. It emphasizes the view that not alone the patient's body but also his mind should be cared for by the physician.

What Is Darwinism? THOMAS H. MORGAN. 78 pp. $1.00. W. W. Norton & Company.

A volume in the "New Science Series," explaining Darwin's theory of natural selection for the general reader; and pointing out that Darwin's "argument for evolution at least is as cogent and convincing to-day as it was nearly seventy years ago."

Our Face from Fish to Man. WILLIAM K. GREGORY. 260 pp. 119 illustrations. $4.50. G. P. Putnam's Sons.

The story of the evolution of the human face—from the stages of the lower vertebrates to those of the ape and man—told in popular language. A detailed study of the origin of our eyes, ears, nostrils and mouth is presented.

Aspects of Age, Life and Disease. SIR HUMPHRY ROLLESTON. 297 pp. $4.00. Macmillan Company.

The author discusses factors influencing longevity, including environment, food, alcoholic drink and smoking. One chapter deals with historical cases of disease, while others present clinical variations and aspects of disease. This is a volume in the Anglo-French library of medical and biological science.

Down Wind. DONALD C. and LOUISE R. PEATTIE. 231 pp. Illustrated. $2.50. D. Appleton & Company.

Sketches of animal life, each one making a bird or beast the center of interest. There are tales on birds such as the heron and the tanager; and there are stories on the bear, the donkey, the tiger and the horse.

Phonophotography in Folk Music. MILTON METFESSEL. Introduction by C. E. SEASHORE. 180 pp. Illustrated. $3.00. University of North Carolina Press.

The purpose of this book has been to demonstrate how phonophotography may be applied to anthropological studies of folk music. The research has been made possible by a grant from the Laura Spelman Rockefeller Memorial.

This Puzzling Planet. EDWIN T. BREWSTER. 320 pp. Illustrated. $4.00. Bobbs-Merrill Company.

This is a popular story of geologic discovery, bearing the sub-title "The earth's unfinished story; how men have read it in the past and how the wayfarer may read it now."

THE SCIENTIFIC MONTHLY

MAY, 1929

ISOSTASY AND GEOLOGICAL THOUGHT

By Dr. WILLIAM BOWIE

CHIEF, DIVISION OF GEODESY, U. S. COAST AND GEODETIC SURVEY

EVERY normal human being is interested in the past history of the planet on which we live and is anxious to know what is likely to take place in or on it in the years to come. We are very much handicapped in studying the history of the earth because the processes which are involved in surface changes and in interior activities are slow in their development. The history of the earth is largely written in the sedimentary rocks which have resulted from the consolidation of sediments deposited in valleys and lakes and close to the coasts of tidal waters. These rocks furnish for our inspection and study the fossil remains of plants and animals.

We know more about the succession of life and its evolution from these fossils than we know of the forces which have tilted, deformed, uplifted and overthrusted the sedimentary rocks in which the fossils are found. We know that forces have been active, for it requires power to lift up high an area that was once at sea level. The plateau of Tibet is more than two miles high, on an average, while the highest peak of the Himalayan Mountains is more than 29,000 feet. These and other uplifted regions are the results of forces acting within the earth itself. Then there are the overthrusts. The geologist tells us that material has been lifted and carried over rocks for a distance of as much as twenty-five miles. The force necessary to overcome the sheering and frictional resistance involved must have been great. By processes of analysis and elimination, we can not find any force outside of the earth itself which could form a mountain or a plateau or bend and twist rocks. We must look within the earth itself.

The interpretation of the history of the rocks that we now see above the water, which, at an earlier time, were below sea level, is made more difficult by reason of the tremendous erosion and shifting of material over the earth's surface which has occurred in the geological past. We see only a fragment here and there and we have, by imagination and by the most logical reasoning that is possible under the circumstances, to try to fill in the missing parts. Then and only then are we able to study effectively the past dynamic history of the globe.

In recent years the studies of the geologist have been placed on a firmer foundation, scientifically speaking, although perhaps his problems may seem to be more complicated, as a result of the observations and investigations of other students of the earth. There are the geodesist whose principal line of activity is the determination of the shape and size of the earth, and the seismologist who is the student of earthquakes. The geodesist has found that the surface of ocean waters and of the waters of sea-level canals, extended in imagination through the continental areas, closely

approximates a spheroid, a mathematical surface. The deviation of this water surface from the spheroid is probably not in excess at any place of 100 meters, approximately 330 feet. The actual earth's surface is, of course, irregular. The deepest part of the oceans that we have found lies just to the eastward of the island of Mindanao, one of the islands of the Philippine group, where a sounding of 35,410 feet was made. The highest elevation above sea-level surface is Mt. Everest, in the Himalayan Mountains, which is approximately 29,141 feet. The difference in elevation of the Mindanao sounding and Mt. Everest is 64,551 feet, or more than twelve miles.

The question may arise as to why the earth is a spheroid. Why does it not have the form of a sphere or a cube? The answer is that the material of the earth is not strong enough to maintain any form other than that of a spheroid. If the earth were compressed into a cubical form and the forces that held it so were suddenly released, there would be a collapse which would bring the earth's surface very close to the spherical form, and this would occur almost instantaneously. The earth has been found to have a rigidity equal to that of steel, but even a steel cube as large as the earth could not withstand the gravitational forces that tend to pull all particles of the mass towards its center. The earth, if it were not rotating, would be very closely a true sphere, but this is impossible with a rotating earth. The radius of the earth at the equator is about thirteen miles longer than half the distance between the north and the south poles. The reason for this is the centrifugal force, due to the earth's rotation. If the earth should rotate twice as fast as it is now doing, this equatorial bulge would be extended and the radius at the equator would be far greater than it is now. On the other hand, if the earth were slowed down in its rotation, the equatorial bulge would tend to settle and the radius at the equator would be lessened.

The seismologists have told us that the earth is solid for at least half of the distance down to the center. Therefore surely seven eighths of the earth is solid, and it is very probable that the other one eighth, which is the ball of comparatively small volume immediately surrounding the earth's center, is also solid. The seismologists tell us that, if the earth were not solid, the elastic waves resulting from earthquake shocks could not travel through the deep parts of the earth. As a matter of fact, they do travel more or less in a true line between widely separated points. An earthquake in Japan will make its occurrence known on the records of the seismograph in San Francisco, for instance. A true line between Tokyo and San Francisco lies 775 miles below the earth's surface at the middle point of that line. The reason that there is some doubt as to the character of the center of the earth is that no earthquake elastic waves have been received at a seismograph station from an earthquake that has occurred exactly on the opposite side of the earth. These elastic waves can not travel through a liquid. They would soon dampen out and disappear. On the other hand the longitudinal or compressional waves can proceed through a liquid as well as through a solid.

The investigators of earth and ocean tides and also of the variation of latitude tell us that the results of their labors indicate very clearly that the earth is rigid throughout or, at least, almost to the center. If the center is liquid, then the rigidity of the remaining part of the earth must be even greater than that of steel.

It will be seen that, as a result of the work of others, the geologists have some accurate data which should assist in their attack on the problem of writing the

geological history of our planet. They know that the earth's water surface deviates only slightly from a mathematical spheroid. They know, from several lines of evidence, that the earth is solid throughout with a rigidity equal to that of steel or, if there is some liquid near the center, the remaining part of the earth has even greater rigidity than steel.

The question may arise as to why we have an earth whose water surface is so nearly a spheroid, which yet has such a tremendously irregular surface. This leads to another line of inquiry which has been conducted rather vigorously by the officials of the U. S. Coast and Geodetic Survey and by others during the past twenty years or more. Some geologists of the last century, in studying the earth problems, were of the opinion that continents were in existence because the material of the earth beneath them is lighter in density than the material under the deepest ocean beds and that, if this were not true, the continents would tend to press down into the earth and push out material under the oceans and, eventually, bring about a uniform elevation of the earth's surface. This, we know and they knew, was not occurring and probably will not occur in the future. There was no way by which the geologist could test these views as to the variable densities of the earth's crust. This was something that had to be tested mathematically, and it is here that the geodesist, who is striving to determine the size and shape of the earth, comes into the picture.

Back in the middle of the last century two English mathematicians and geodesists, G. B. Airy and J. H. Pratt, attempted to determine the shape and size of the earth and the lengths of degrees of latitude from geodetic and astronomic data in India. The geodetic data consisted of determinations of latitudes and longitudes and the measurement of distances across the country by means of measured base lines and triangles whose angles were accurately measured. If one side of a triangle and its angles are known, the lengths of the other sides can be computed. This principle is employed in nation-wide surveys of all countries. These triangulation stations, whose latitudes and longitudes can be computed when the shape and size of the earth are at least approximately known, furnish the framework for various types of surveys and maps. The astronomic data were the latitudes determined by observations on the stars.

Since the earth's water surface is approximately a spheroid, a degree of latitude near the equator would be shorter in linear measure than a degree of latitude which is nearer the pole. Pratt and Airy in working over the India data found such wide divergences between the latitudes, as determined astronomically, and those determined from the triangulation that they were led to believe that they should apply corrections for the attraction of the visible masses above sea level and the deficiency of mass in the Indian Ocean. The necessary computations were made and corrections were applied. Then the astounding fact presented itself that the computed values for the attraction for these great land masses were much larger than necessary to bring the triangulation and astronomic latitudes into accord. Each of the investigators arrived at the conclusion about the same time that apparently the Himalayan Mountains were hollow or that there were hollows in the outer portion of the earth just under the mountains or that the densities of rocks under the mountain and plateau areas must be less than normal. The triangulation and astronomic data could only be brought into accord by the existence of one of those conditions. Pratt and Airy wrote papers setting forth their views on this important mat-

ter. This equilibrium theory of Pratt and Airy was later called isostasy by the late Major C. E. Dutton, of the U. S. Geological Survey. Isostasy is a term derived from the Greek and may be defined as equal standing or equal pressure. According to the isostatic idea, the outer portion of the earth exerts an equal weight for equal areas at some unknown surface below sea level. The views of Pratt and Airy and of Dutton did not, for a number of years, receive much attention by the scientific world.

Even the small number of advocates of the isostatic theory were very much discouraged because they could not see any practicable method of testing it. However, about twenty-five years ago officials of the Coast and Geodetic Survey decided that the isostatic theory would have to be taken into account in the determination of the figure of the earth which they undertook. In this determination were used the latitudes and longitudes determined by observations on the stars and those that were dependent on the measurements of distances across country by triangulation. It was believed that the pull of the mountains on the plumb bob, which would deflect it, would be, to a certain extent, neutralized by the deficiency of material under the mountains if isostasy were true. The effect of the attractions of the mountains and plateaus and other land masses and also the deficiency of matter in tidal waters contiguous to the United States were computed. There were also computed the effects of the deficiency of the density below the continental areas and the excesses below the ocean areas which according to isostasy would offset the positive and negative masses at the earth's surface.

In order that isostasy might be tested, certain assumptions regarding the outer portion of the earth had to be made. The first one was that isostasy is perfect—that is, that each prism of the earth's crust down to a certain unknown depth has exactly the same mass as any other prism of equal cross section. Second, that the compensating deficiency or excess of mass lies directly beneath the topographic feature. Third, that the lower limit of the outer portion of the earth in which these heterogeneous densities occur extends to a uniform depth below sea level. Fourth, that the densities of the earth's material above sea level average 2.67 and that the deficiency in sea water is 1.64. None of these assumptions was thought to be absolutely true but they had to be made in order to carry on the work.

Computations were made of the effect of the compensating deficiency and excess of mass distributed to depths varying from ten miles down to about 160. For a depth of about seventy miles, the triangulation and the corrected astronomic latitudes and longitudes came into the closest agreement. In fact, for that depth the differences were exceedingly small. This was a great victory, for it proved that isostasy is probably true. Later, investigations of isostasy involving the values of gravity were made by officials of the Coast and Geodetic Survey.

The values of gravity on a perfectly smooth-surfaced spheroidal body would increase gradually and according to a definite law from the equator towards the poles. This for the earth has been found to be true only to a limited degree. There are disturbing influences involving the masses of the continents and the deficiency of mass in the oceans and the counterbalancing changes in density in the crust beneath them. Therefore, when we reduce our values of gravity to sea level, without taking into account these other factors, the results are very irregular and do not agree well with the theoretical values. However, when the effects of what may be called the topography and the compensation of the

topography are applied to the observed values of gravity these agree very closely with the theoretical ones. The results of the isostatic investigations involving the values of gravity confirm the results that had been obtained from the use of astronomic and triangulation latitudes and longitudes.

The values of gravity used in the isostatic investigations have now been extended widely over the earth's surface. In addition to the United States, gravity data in Canada, India and several states of Europe have been used in isostatic investigations, and for each region isostasy has been found to be substantially true. For many years there has been much speculation as to why the ocean beds are two or three miles lower, on the average, than the continental surfaces. The isostasist claimed that the depression is due to heavier material in the crust under the ocean areas. The question though was a debatable one until a few years ago when Dr. F. A. Vening Meinesz, a member of the Dutch Geodetic Commission, devised an apparatus with which to determine gravity at sea. In this operation, he used a submarine of the Holland navy which was submerged to a depth of about seventy feet at the time of the observations. At that depth the boat is nearly free from the effect of the oscillations of the ocean surface. Dr. Meinesz has circumnavigated the globe in submarines, making gravity observations *en route,* and during last October and November he used his apparatus on a submarine of the U. S. Navy in the Caribbean Sea, the Gulf of Mexico and the Atlantic Ocean between the eastern end of Cuba and Chesapeake Bay. The values of gravity at sea have enabled investigators to show that isostasy is just as true for the earth's crust under the oceans as it is for land areas. We may now assert that isostasy is an established scientific principle.

In order that isostasy may be true, the material of the outer portion of the earth, called the crust, must have what is called residual rigidity; that is, it resists for long time the stresses which tend to make the surface a perfectly flat and smooth one. Below the crust, however, there must be material that is plastic to long-continued stresses. It is rigid to the tide-producing stresses exerted by the sun and the moon as the earth rotates on its axis but those forces act for only a small period of time for any particular part of the earth. They change phase every few hours. Just what causes the change in the physical condition between the crustal and subcrustal material is not known, but it must be a result of the temperatures and pressures which exist at a depth of approximately sixty miles, the best value obtainable for the lower limit of the crust.

With isostasy proved, we must try to learn what is going on in or on the earth to change the surface configuration. We know that each mountain system occupies an area that was once below sea level and on which sedimentary material to great thicknesses was deposited in shallow water. We know also that the mountain or plateau areas, from which those sediments were derived, have been brought to or below sea level. It would seem that there is no such thing as the "everlasting hills." What is now above sea level will probably, at some time in the distant future, be submerged, and recent sediments placed in areas now at or below sea level will be pushed up as mountains.

As material is eroded from the continental areas and deposited in tidal waters, the crust beneath the latter sinks down under the added load, and areas from which the sediments were derived rise up, but the rising will not be as great as the thickness of the material that has been eroded away. For instance, if a thousand feet of material is eroded away from the Rocky Mountain system, it is probable that the area will be restored in elevation to an extent of only 800 feet. This is because the density of material

beneath the earth's crust which is moved horizontally from the area of weighting to the area of unloading is greater than that of the material at the surface. We do not know what is the density of the subcrustal rock, but it is surely three times that of water, or more. The surface density is 2.6 or 2.7, while the average density of the earth as a whole is 5.5. Therefore the earth increases in density from the surface towards the center.

In searching for the causes of the changes in the earth's surface which do not do violence to the principle of isostasy, we are led to believe that the most effective agency is erosion of material from the land areas and the deposition of this eroded material in tidal waters. There may be, and probably are, other factors, but this one is adequate to make an enormous amount of disturbance.

The geologists and geophysicists estimate that the time elapsed since the beginning of sedimentation on the earth is about a billion and a half years. It was at the beginning of that time that water began to fall to the earth and to run in streams and rivers to the low places.

The amount of rainfall now is approximately thirty inches per annum for the land areas of the earth. If this rate should have been maintained during the whole sedimentary age, we should have had about three fourths of a million miles of rain. Of course, there is not that much water on the earth, but this is not necessary. The heat of the sun evaporates the water of the ocean and the saturated atmosphere drops its burden over the land areas and the water again goes to the sea. If the earth were uniformly covered with the waters of the ocean, the depth would be approximately 9,000 feet, or nearly two miles. The amount of rain that we have had is enormously greater than this, so we must have used the ocean waters over many times during the sedimentary age. The evaporation and precipitation and the runoff form a continuous process and will go on as long as the earth receives heat from the sun.

The amount of erosion from land areas is very great in the aggregate. The officials of the U. S. Geological Survey estimate that about one foot, on the average, is eroded from the surface of the United States in 9,000 years—that is, the amount of material that is carried by the rivers and streams to tidal waters and there deposited. This rate would mean, if continued, a mile of erosion in approximately forty-five million years. During the sedimentary age, which is a billion and a half years in duration, we could have had approximately thirty miles of material eroded if there had been a supply so vast. All of this means that any given high area is, in a comparatively short geological time, worn away and reduced to sea level. Then, of course, erosion and sedimentation, as we know the process, cease for that particular region and the adjacent tidal waters but, while that particular high area might have been in process of wearing down other areas would be building up new mountains. Geologically, we speak of periods of active mountain building and other periods during which no mountains were formed. I am rather inclined to think that the formation of mountains and their wearing away are not confined to any particular geological period. They are continuous processes and, in fact, just as continuous as are sunshine, evaporation and rainfall.

The question is frequently raised as to how there could be any runoff of the water during the first rainfall. Was not the earth's surface at that time uniform in height? The answer to this seems to be that the earth had as great irregularities at the time that water first began to fall as it now has. In fact, it would seem that there were greater differences in elevation between the uplifted areas and the depressed ones at

that time than now. In any event, we could not have had running water without an irregular surface and we could not have had erosion and sedimentation without running water. We have abundant evidence that erosion was going on at a very rapid rate in the earliest part of our sedimentary age.

Many theories have been advanced to account for the ocean basins and the continents. The only one that appeals to me as being logical and not doing violence to the principle of isostasy was advanced by Osmond Fisher about forty years ago. Darwin had previously shown that the moon is gradually receding from the earth and that at one time in the distant past it was so close that he was led to the idea that it may have been a part of the earth and had become detached from it. Fisher indulged in some speculation in a very interesting book entitled "Physics of the Earth's Crust," and suggested that the moon pulled away from the earth at a time when a solid shell had formed all around the earth. If the moon had left the earth when the latter was a fluid there would have been no irregularities left in its surface. But it is quite conceivable that, if the earth had lost the moon from the area of the Pacific, after the solid shell to the depth of thirty or forty miles had been formed, the lighter material near the surface would have been thrown away, leaving great gaping wounds. These would have been healed by the upswelling of the subcrustal material which, necessarily, would have been denser than the material that was drawn away. Being denser, its surface would not rise to the height of the original material. A denser layer of subcrustal material thinner than the disrupted crust would just balance the portion of the outer solid shell which had remained after the catastrophe involving the moon's formation. The remnants of the crust that were left would be the present continents and oceanic islands. They would have been fragmented by the terrible commotion that would have been caused by the disruption. We can imagine that the crust under North America and South America would have drawn away from that under Europe and Africa, and that Australia and the East Indies would have been dragged away from the area now occupied by the Indian Ocean. All of this is, of course, pure speculation, but it is certainly a simple theory and one that can account for the presence of continental areas which are underlaid by granite, a light material, while the oceans are underlaid by basalt, a heavy material.

The establishment of the principle of isostasy leads us to the conclusion that earthquakes may be a result of the shifting of great masses across the earth's surface as a result of rainfall. The isostatic equilibrium is undoubtedly maintained at all times. This means that the crust of the earth under the sediments must be pushed down. It is formed of brittle material, and under the great loads will be fractured. When the fracture occurs a vibration is set up which may, if the earthquake is large enough, travel all around the earth and also through it. Then the area of erosion which has been made lighter is pushed up by the subcrustal material. There again the crustal material is brittle and when the forces are too great it snaps and sends out its vibrations. Then we have the process of mountain building which takes place in all cases, as far as we know, along margins of inland seas and ocean areas where sedimentation had been heavy. In the process of uplift to form the mountains the earth's crust is ruptured and earthquakes occur. We also have the sinking of the areas which previously were occupied by mountains, and during the process of sinking the earth's crust is again broken and earthquakes result. This building of mountains and the sinking of former moun-

tain areas must be due to the changes in the temperature of and pressure on the crustal matter which lies beneath the areas of sedimentation and erosion.

We therefore have four causes of earthquakes which are quite in accord with the isostatic principle. There may be other causes of earthquakes but we do not see so clearly what they are. It is quite evident that they are caused by erosion and sedimentation, the building of mountains and the sinking of former mountain areas below the sea.

It would seem that volcanoes are, in a way, closely allied to erosion and sedimentation. Volcanoes along mountain areas probably occur in zones of fracture, in what we call fault zones, where also great earthquakes must have occurred. At the time of an earthquake the rocks must have been fractured and fissured to a considerable depth, say ten to 20 miles. Into the vents thus formed, magmatic material must have swelled upward, or if the outer rock were only crushed and fractured the igneous rocks now soft or liquid must have pushed through the fragments to the surface. Of course, the earth's crust is solid throughout, except possibly in small spaces, but with a fracture extending twenty miles below sea level the hot material at that depth with the release of pressure would become plastic or liquid and move upward. In order that the volcanic theories may not do violence to the isostatic principle the cause of the volcanoes must be an expansion of the earth's crust beneath. If this is true, then the volcanic cone formed at the surface of the earth is not an extra mass added to the prism of the crust on which it rests. Of course, the cone is an extra load on the earth's surface, but there must have been no increase, as a result of the formation of the volcano, to the weight exerted by the prism on the subcrustal material.

Isostasy has certainly come to stay, and the geologists of to-day are using the principle more and more in their interpretations of the earth's history and what is to happen in the future. Surely the geologist who runs counter to the isostatic principle is likely to run into grave difficulties.

The earth is not a rigid, strong, unchanging mass. It is yielding to the changes of load at the surface and would change to conform to any shift of its axis or of its rate of rotation. Probably we are better off with a yielding earth than with a very rigid one, for, otherwise, great stresses might accumulate through millions of years and then when the rupturing came the disaster might be tremendous and overwhelming. We shall have changes in the earth's surface, earthquakes and volcanoes as long as we have sunshine and rain. Without sunshine and rain we should not be very much interested in anything else that might occur.

QUALITY IN GRAPES

By Professor FREDERIC T. BIOLETTI
UNIVERSITY OF CALIFORNIA

A FEW years ago when the shipping of wine grapes from California was beginning to tax the facilities of the transcontinental railroads, two of my viticultural students asked me to arbitrate a dispute as to the relative qualities of Alicante Bouschet and Petite Sirah. One student, who was from Sonoma, stated emphatically that the Sirah was of much superior quality, but could defend his opinion only by saying that this was a fact of common knowledge. The other student, who was from the San Joaquin Valley, stated with equal emphasis that the Bouschet was undoubtedly of higher quality, and backed his assertion by the fact that it brought twice the price of the Sirah in the New York market. I had to decide for the man from Sonoma, but with almost as much difficulty in defending my opinion.

DEFINITION

The decision must depend, in fact, on how we define "quality"—what we mean by the term. If we mean that which makes a thing "profitable" apparently the San Joaquin man was right. But this is hardly admissible. A manuscript accepted by the *Saturday Evening Post* may bring a higher price than one accepted by the *Atlantic Monthly*, but this is not a good measure of its relative quality. In general literature, the word has various meanings. Used in the singular—quality—it is commonly given the abstract meaning of excellence or degree of excellence. Used in the plural—qualities—it is commonly a synonym of characters, characteristics or peculiarities. This distinction is not absolute and the sense intended can be inferred only by the context. When used without qualification, it generally refers to desirable characters. If intended in the opposite sense, it is accompanied by a restricting adjective such as "bad" or "undesirable."

In technical and scientific literature, it is necessary for clarity that each special term shall be used in only one sense and defined as precisely as possible. For our purpose, quality may be defined as the sum or resultant of the *intrinsic* characters of the grape which *give satisfaction to the consumer*. This is in accord with the dictionary definition of "degree of excellence," and excludes price. Price may be enhanced by rarity or other extraneous factors. The quality may affect the price, but the price does not change the quality. This definition, however, is not quite complete because the tastes or preferences of consumers vary, and the taste of the same consumer varies with his experience and his physical condition. A more exact definition is: "Those intrinsic characters which please the most experienced and best-instructed normal consumer." Without experience, a consumer might fail to appreciate the quality of the best Camembert cheese, and a consumer who had been brought up on Concord grapes might fail to find any quality in Black Hamburg. Taste is a matter of both idiosyncrasy and habit, and therefore varies with the individual. This does not mean, however, that there is no standard of taste. Individual tastes vary about a mode, and, as experience accumulates, this mode becomes more definite and gradually moves towards a position that represents the standard of taste of an experienced community.

The nearer our grapes approach this standard, when they reach the consumer, the more we can market and the

higher price we can obtain ultimately. We may be able to market Emperor grapes more successfully than Muscat of Alexandria or Rose Damascus in New York because we are able to get them there in better condition. The Muscat and the Rose Damascus may be of higher quality, more attractive in appearance and eating quality when packed, but too delicate to ship well and may have lost all their good qualities when they reach the market. It is the quality of the fruit when it reaches the consumer that is of importance. However high the intrinsic quality of a variety, it is of little value unless the climate, soil and cultivation of the vineyard enable it to produce fruit of this quality, and unless our methods of handling enable us to preserve this quality until it reaches the consumer. We must not only select a good variety, but we must give it the conditions it needs and handle it properly.

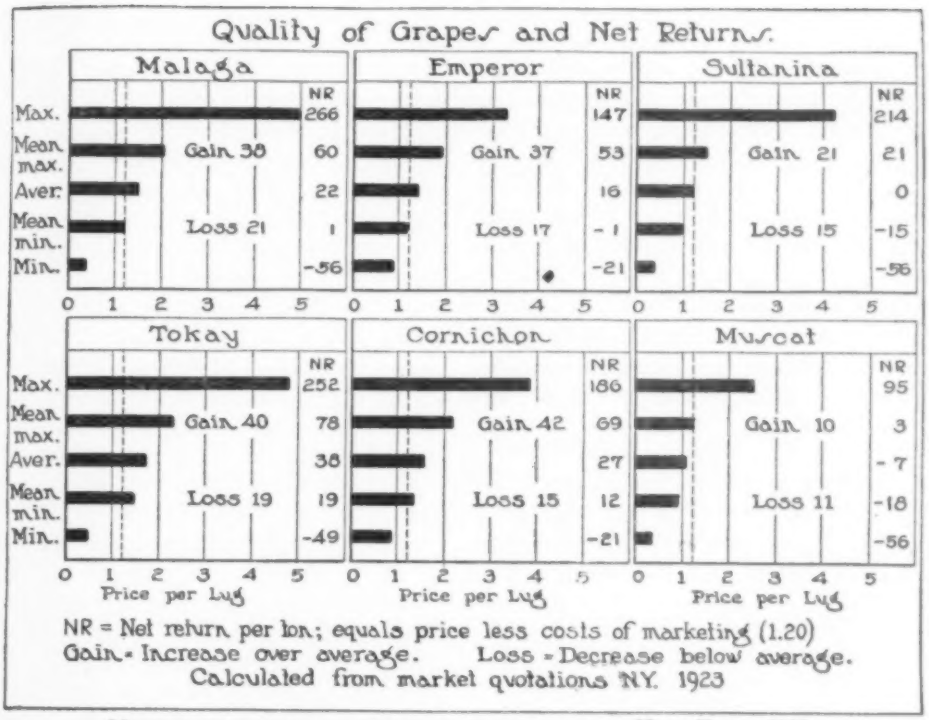
Although the Rose Damascus is extremely brilliant and attractive to the eye and the Muscat richly and delicately flavored, and both more pleasing in all the characters which constitute "quality" when they are harvested, they can not compete with much inferior varieties when they reach a distant market. This is because they lack the keeping and carrying characteristics which enable us to get Emperor grapes to distant markets in as nearly perfect condition as they leave here.

If by improved methods of packing and storing we could preserve the high qualities of our best grapes until they reached the consumer, some of the grapes we now grow would take a lower place in our vineyards, and some of the grapes we grow little and ship less would take a much higher place.

Commercial Value

The variation in price which different varieties owe to their intrinsic quality is less in most cases than the variation due to the condition of different shipments of the same variety. This is shown graphically by the chart. The highest mean daily maximum price for the season was \$2.31 for Tokay, followed by \$2.19 for Cornichon, \$2.05 for Malaga and \$1.95 for Emperor. The average price for these different varieties arranges them in the same order. This variation may be considered to represent principally the relative intrinsic quality of the *varieties* in the opinion of the consumer, and has an extreme range of 100:85. The range between the mean daily maximum and mean daily minimum of the same variety, however, is greater. In Malaga it was 100:74; in Tokay, 100:63; in Emperor, 100:61, and in the Cornichon, 100:41—an average of 100:60. This variation may be considered to represent the variation in *condition* of the various lots as they reached the market. This variation is due (1) to the quality of the grapes when they are harvested and (2) to the degree of skill and care with which they are handled in harvesting, packing and shipping.

The four varieties considered constitute the main crop of Californian table grapes. The other two varieties shown on the table and chart are raisin grapes and only shipped as table grapes in a limited way or occasionally. The Sultanina is shipped, principally and usually, as the earliest grape of the season, while the shipping of Muscat as a table grape is usually confined to comparatively near markets. The average price obtained for these varieties was so low in 1923 that the Sultanina as a whole returned nothing to the growers and the Muscat caused them an average loss of \$7.00 a ton. The cause of this was partly the poor shipping quality of these varieties, especially of the Muscat, but principally oversupply. That under favorable conditions these varieties can



MARKET QUOTATIONS OF PRICES OF FRESH GRAPES. NEW YORK, 1923. (MARKET NEWS SERVICE. U. S. D. A.)

be shipped to New York with profit is shown by the maximum price of $2.55 a box obtained for Muscat—a price that would return the grower about $95.00 a ton. The maximum price received for Sultanina is even higher, but this represents very early grapes which sold on a bare market. The effect of quality due to condition irrespective of variety is shown by the range between the mean daily maximum and the mean daily minimum. This was 100:65 with the Sultanina and 100:76 with the Muscat. The average variation of price due to condition of grapes which were in good demand was 100:60; of grapes in poor demand, 100:70; and the variations due to the variety of grape only 100:85.

FACTORS OF QUALITY

We have defined "quality" as that sum or combination of characters in the grape which makes an agreeable impression on the consumer. This does not tell us what these characters are. As they make their impression by their effect on the senses, they can be classified in accordance with these senses. The senses affected are those of sight, taste, smell and touch. These are arranged in the order of time in which they function, not necessarily of their importance.

Appearance. The first impression is made by the sense of sight. If the color, size and form of the grapes are unattractive the prospective buyer loses interest.

Color. Bright colors are attractive. The clear black of the Gros Colman, the brilliant red of the Tokay, the golden yellow of the Sultanina, are particularly attractive. Less distinct colors when united with large size of berry are also pleasing, as, for example, the deep plum

red of the Molinera, and the bronzed greenish yellow of the Malaga. The essential point is that there must be as little variation as possible among the berries of a cluster or package. A mixture of white, pink and red, such as occurs in an ill-colored Tokay, or of green, white and black, in a dense cluster of Black Morocco, is not prepossessing.

The principal use of a brilliant color is to attract the new or uninstructed buyer. If the other qualities are inferior, the buyer soon learns to associate the color with inferiority and the color then becomes a disadvantage. On the other hand, in an experienced market, even a neutral or dull color, such as that of the Traminer or of the Chasselas, may be preferred if it is associated with excellent eating qualities.

Size. Large size, like bright color, always attracts the new buyer. The large black berries and clusters of the Gros Guillaume will sell in competition with the smaller black berries of the Muscat Hamburg to a buyer unacquainted with either of them, but most consumers would reverse their preference after eating a few of each. The case is similar with the large, oval, green Chaouch, and the small, round, green Madeleine Angevine, two extremely early grapes which ripen about the same time.

Form. Unusual form is attractive principally on account of its rarity. There seems to be no other reason that preference is given to the form of the gherkin-shaped Pizzutello and the spindle-shaped Rish Baba over that of the nearly spherical Palomino and Malvasia bianca, except that the latter is the form most commonly occurring in grapes. The attraction of unusual form, however, is real and permanent if it is accompanied by other pleasing qualities.

The impression made on the sight is followed by that made when the grapes are eaten. The grape has a taste, an aroma and a texture.

Flavor. The flavor of a grape, as this word is commonly used, is a combination of the sensations of taste perceived in the mouth with those of smell produced in the nose through the medium of the inner nasal passages. The term "taste" is often used as synonymous with flavor, but it aids in precision to confine this term to those sensations which are perceived only in the mouth and to use the term "aroma" for those sensations which are perceived by means of the organ of smell and which are undetected if a grape is eaten while preventing the passage of air through the nasal passages.

Taste. The taste of a grape consists of the sensations it produces on the tongue and other parts of the mouth as distinct from the aroma, which consists of the sensations produced in the organs of smell through the internal nasal passages. There are supposed to be only four fundamental tastes—sweet, bitter, acid and saline. Variations in taste represent various combinations of these. A bitter or a saline taste is a defect in grapes. The sweetness and acidity affect the quality by their quantity and their ratio.

The sweetness due to sugars and the sourness due to acids neutralize the effect of each other on the palate to a certain extent. A grape with 19° Balling (19 per cent. of sugar) and .5 per cent acid will taste sweeter than another with 22° Balling and 1 per cent. acid. In considering the effect of sugar and acid on quality, this should be kept in mind. In standardization regulations with grapes, only the Balling degree or sugar is considered. This, in most cases, is a sufficient guide, because as the sugar increases to its optimum the acid increases to its optimum. If we find the most favorable sugar content in a well-grown, sound grape, the

sugar:acid ratio will generally also be favorable.

There are some difficulties here caused by variation due to variety and to locality. In the cooler regions, the sugar: acid ratio increases more slowly than it does in the warmer regions. The result is that the grapes have attained their required degree of color, flavor and other factors of quality while the sugar is comparatively low and the acid comparatively high, with a corresponding low sugar: acid ratio. In the warmer regions, on the contrary, the sugar: acid ratio increases more rapidly than the color, flavor, etc., and in order that the grapes shall have their optimum quality, they must contain more sugar and be harvested at a higher sugar: acid ratio.

There is the same contrast between varieties. A Tokay may require 22° Balling and a sugar: acid ratio of 44 to be very attractive, while the Alphonse Lavallée may reach a corresponding stage of maturity at 20° Balling and a sugar: acid ratio of 38.

The sugar: acid ratio alone is unreliable as a measure of quality because the terms can be changed indefinitely without altering the ratio. It is possible that an ill-nourished grape, grown on a weak or much overloaded vine, and a properly developed grape of the highest quality may have the same ratio. The first grape might have 15 per cent. of sugar and .5 per cent. of acidity and the second 24 per cent. of sugar and .8 per cent. of acidity. Each would have a sugar:acid ratio of 30, but one would be inedible, lacking in sugar, acid and flavor, and the other would be of excellent quality in all respects.

Aroma. There is no common word in English to distinguish the sensations due to the sensibility of the organs of smell as affected by the passage of substances or gases from the mouth through the internal nasal orifices. There is, on the other hand, a plethora of terms to designate the sensations arising by way of the external orifices—odor, fragrance, perfume, scent. The word aroma is sometimes used to include both cases, but it is convenient to restrict this term to the sensations due to substances affecting the sense of smell through the inner orifices. Those entering the external orifices can be called odors, but as grapes have little special odor perceived before eating, this is of little importance.

Certain grape aromas are very special. Some such as those of the Muscats, the Malvoisies and the Cabernet, Semillon and Riesling are pleasing. Others such as those of the Zinfandel, Mataro and most Labrusca varieties are less so. All grapes have some aroma, but in most cases of viniferous grapes it is simply what is commonly known as a vinous aroma or flavor, and while differing for different varieties, the differences are subtle and difficult to describe and distinguishable only by a sensitive and experienced palate.

The aroma increases as the grapes ripen and is the principal factor of quality after those of sugar and of sugar:acid ratio are satisfied. The value of allowing most varieties to mature beyond the stage at which the sweetness is sufficient is the increase of aroma. Not only highly aromatic grapes such as Muscat improve in this way but even grapes of milder and more subtle aroma such as Malaga, Tokay and Sultanina.

Touch. The characteristics of texture and structure of pulp, and of thickness and toughness of skin, and perhaps of astringency are perceived by their effect on the sense of touch. Grapes just before they ripen are firm and tough or crisp. As they ripen, they develop various textures. The pulp of some becomes more and more liquid (Pinot and Burger) until the berry resembles a bag of liquid. Others remain crisp (Palomino, Tokay), but quickly break up and

release their juice when eaten. Others remain firm (Perruno, Chauché), and require more masticating to be disposed of. Others retain some of their firmness but become somewhat gelatinous (Muscat, Alphonse Lavallée). Others become soft and more or less juicy (Rish Baba); a few become soft but not juicy, almost mealy (Zabalkanski). The Labrusca varieties (Concord, Pierce) develop in a different way. The central portion of the berry around the seed remains firm and relatively sour, and the skin and adhering layers of the pulp retain the same characters in a minor degree, while the larger layer between becomes juicy and sweet.

Most of the wine grapes are juicy. This is doubtless because no attention has been given to texture in the selection of these grapes, and they have retained this character of the wild *V. vinifera*. Most table grapes, on the other hand, are more or less pulpy or firm because this is a valuable property for handling and keeping and is more agreeable in a fruit to be eaten fresh and has therefore been considered in selection.

Production of Quality

When the nature and value of quality are known, the problem is how to obtain it. It depends: first on the variety; second on the environmental conditions such as climate and soil, and how well they are suited to the variety; and third on the methods of culture, including all the arts of the grape-grower.

Ideals. To strive intelligently for the "best quality" we must know in detail the concrete facts on which this term is based for each variety. Of the numerous details which determine quality some are common to all grapes and some are required only for certain varieties or vary for different varieties.

The qualities considered necessary for the highest grade are:

(1) Good condition—freedom from blemishes due to decay, drying or mechanical injury.

(2) Perfection of cluster—moderate size and normal form; well filled but not too compact for easy and proper packing.

(3) Perfection of berry—large size for the variety (this applies even to varieties of normally small size such as Black Corinth and Sultanina); even coloration of each berry and of all berries; color normal for the mature fruit of the variety or, where this differs in different localities, the color preferred by the market—the red of the Emperor grown in Tulare County is preferred to the deep purple which is normal in cooler regions or different soils.

(4) Full maturity as evidenced by sweetness, flavor and texture.

These factors of quality apply to all varieties, but some modification of degree is necessary with some factors for grapes used for different purposes. For dry-wine grapes, less sweetness is desirable than for table grapes. This does not necessarily mean less sugar but a lower sugar: acid ratio. For raisins, on the contrary, the highest possible degree of sugar and a high sugar: acid ratio is best.

To obtain the highest quality requires somewhat different methods with different varieties, but it is possible to give the general conditions needed in all cases and to indicate the necessary modifications in special cases.

First, we must have a variety suitable to our purpose and to our market. No method of culture can make a good table or raisin grape out of a Zinfandel, and no method can produce an Emperor fit for wine-making.

We must then have a locality suitable for the variety and the purpose. The Ohanez will not ripen in cool Sonoma County and the Chasselas doré will be small and unproductive and lose most of its delicacy in hot Kern County. The soil must be suited to the variety, though this is not usually so important and it can be ameliorated more easily than the climate.

When we have a suitable variety, growing on a suitable soil, in a suitable climate, our success in producing full crops of grapes of high quality depends on our cultural methods. To describe all these cultural methods would require a treatise on viticulture. I will, therefore, point out only some of the special methods of culture which tend to increase the quality of the grapes.

Training, Pruning and Thinning. These operations must be discussed together as one can not be carried out properly except with reference to the others.

The best grapes are produced on well-nourished, vigorous vines which have ripened their wood and buds perfectly the preceding autumn. They will be best only if each vine and each branch bear no greater weight of grapes than they can bring to perfect maturity. Long pruning tends to strengthen the vine by increasing the area of foliage and the time during which it is active. At the same time it tends to the production of excessive crops which are beyond the capacity of the vine to bring to perfection. The net result is often to weaken the vine and decrease its capacity for the following year.

Both of these defects can be avoided by long pruning followed by sufficient and timely thinning, *i.e.*, removal of excessive blossom clusters from the vine or of excessive berries from the cluster while they are very small.

Distribution of the Clusters. A vineyard may not have a very large crop, yet most of the grapes may be on the average inferior because a large number of the vines overbear and hence produce poor grapes, while others produce little or none. The same may occur with individual vines. One arm of the vine may be so loaded that the grapes are small and fail to ripen, while the rest of the vine may have very few.

This defect is avoided by "differential pruning," or better still, by differential thinning. If the weaker vines are pruned shorter they will produce fewer grapes, but grapes of better quality, and the vines will gain in vigor for the following year. If the stronger vines are pruned longer they will produce more grapes, and if too much wood is not left, the grapes will be of good quality and not sufficient in volume to weaken the vine.

As the amount of wood we leave on a vine has a direct ratio to the subsequent growth and vigor of the vine, and as the amount of crop has an inverse ratio, our best plan, where it is practicable, is to leave a generous amount of wood on all vines—strong and weak—when we prune them, and then to limit the crop in the spring by cluster thinning, and, where necessary, by berry thinning, to bring the amount of crop within the capacity of each vine and of each part of each vine.

Clearing the Clusters. A vine may produce many clusters of fine grapes and yet many of them can not be harvested without being seriously injured because they have grown around shoots or interlocked with each other. A fine cluster can be gathered, packed and shipped in perfect condition only if it hangs and develops free from all entanglements.

This is accomplished in the first place by training and pruning the vine so that it spreads sufficiently to allow each cluster full room to grow without touching another. "Head suckering" is used for removing the shoots which might grow through the clusters, but this practice is generally inadvisable because it has a depressing effect on the vines like all pruning, especially the removal of actively growing parts. A better plan is to go over the vineyard when the clusters are formed and the berries about one third grown and clear each

cluster from other clusters and from shoots with which it is entangled. This is easy at this stage and can be done without injury to the grapes. If not done at this time, it must be done at harvesting, when it is more difficult, requires more time and seriously injures or spoils the fruit.

Ringing. This operation, called also "girdling" and "cincturing" and "annular incision," consists in the removal of a ring of bark about one eighth of an inch wide (.1 in. to .15 in.) from the trunk near the surface of the soil or from an arm or a cane below the fruit which it is intended to affect. The smaller the part operated on, the narrower the ring. The effect is to cause the carbohydrates elaborated in the leaves to accumulate in the parts above the wound, including the clusters of blossoms and fruit. The result is that the berries grow larger and usually ripen earlier. If done before blossoming, it promotes setting and thus increases the number of berries. In some cases the increased setting may so increase the number of berries and weight of cluster that the fruit is neither larger nor earlier. In such a case the girdling should be followed by berry thinning.

Girdling is a form of summer pruning and is weakening, in some cases greatly so. Only very vigorous vines can withstand its yearly repetition. It is of much less general application than the other methods mentioned, and in general should not be resorted to until as much improvement as possible has been obtained by the other methods.

LAMPREYS AND THEIR WAYS

By SIMON HENRY GAGE

PROFESSOR EMERITUS OF HISTOLOGY AND EMBRYOLOGY, CORNELL UNIVERSITY

THE lampreys,[1] or lamprey eels, are water animals of an elongated, eel-like form. They are usually called fishes, as are most water animals from whales and dolphins to jelly fish. While they are usually described in works on zoology with the fishes, they are not true fishes like the trout, bass, etc., but very much lower in the zoological scale. They have no bones and no paired fins corresponding to the arms and legs of higher forms, and they have no scales. Lampreys do have a dorsal and a good tail fin, and excellent gills. Instead of one gill opening like that in the true fishes, they have seven gills on each side, each with its own opening. The paired fins of fishes and the seven gill openings are shown in Fig. 1; and the gill openings of the lamprey, in most of the accompanying illustrations.

Lampreys are found in the fresh waters and the oceans of both hemispheres. All begin their life in fresh water, and some remain there always, but others spend a part of their life in the ocean. Wherever they may live, at maturity they all go up into the fresh-water streams in the spring (April, May, June) to lay their eggs. As there are more fresh-water lakes and streams in the larger land area of the northern hemisphere, so there are more lampreys in the northern than in the southern hemisphere.

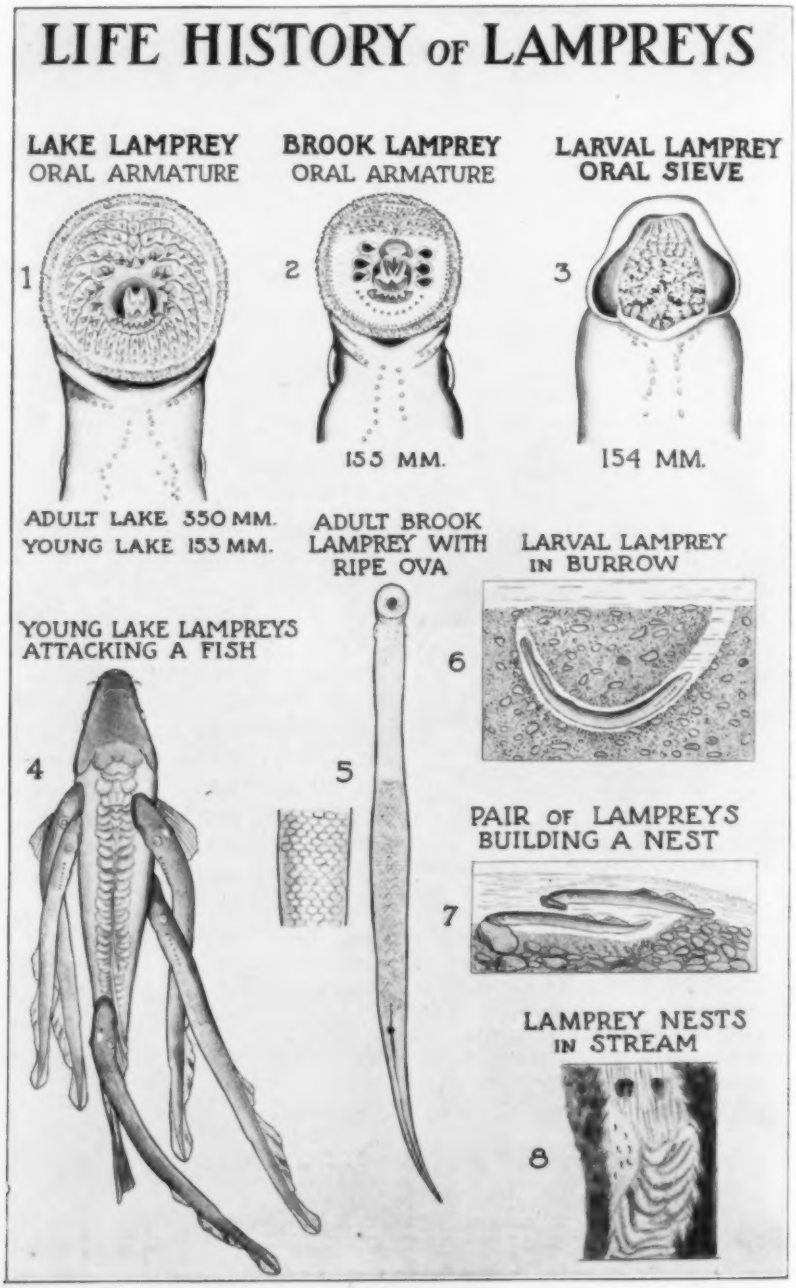
In New England, the large sea lampreys go up many if not all of the rivers to spawn. For example, they are found at the spawning time in the Merrimac, the Connecticut and their tributaries. In New York state the sea lampreys go up the Susquehanna, the Delaware, the Hudson and some of the streams of Long Island. Those that live entirely in fresh water are found in the streams flowing into the Great Lakes, the Finger Lakes and into the Allegheny River. They are also in some of the streams of New England, New Jersey, Maryland, the Mississippi basin, coastal brooks of the Pacific, and many of the streams of the old world.

[1] In North America there are at least four genera of the lamprey family (Petromyzonidae): Petromyzon, Ichthyomyzon, Entosphenus and Lampetra. All the members of the genus Petromyzon (sea and lake lampreys) of the Atlantic region, some members of the genus Entosphenus of the Pacific region, and some also of the genus Ichthyomyzon of the Great Lakes and the Mississippi basin, are parasitic in their adult stage. The brook lampreys, spending their whole life in the fresh-water streams of both Atlantic and Pacific regions, are small in size and are not parasitic at any stage. They are represented by the genus Lampetra and by representatives of the genera Ichthyomyzon and Entosphenus.

From Science, September 23, 1927

FIG. 1. LAKE LAMPREY ATTACHED TO A FISH

ABOVE THE PECTORAL AND VENTRAL FINS ARE SCARS SHOWING WHERE OTHER LAMPREYS HAD MADE RAGGED OPENINGS WITH THEIR RASPING TONGUE.



From the N. Y. State Conservation Department

FIG. 2. LIFE HISTORY OF LAMPREYS

All lampreys, wherever found, have two great stages in their life cycle: a young or larval stage, corresponding with the tadpole stage of the frog and the caterpillar stage of butterflies and moths; and an adult stage. The larval stage is always spent in the mud of fresh-water streams. The adult stage of some is passed in fresh-water lakes or streams, while with others a part of the adult life is spent in the ocean.

While the larval lampreys do not look so different from their parents as do caterpillars and tadpoles, yet their mode of life and internal structure is fully as great. The larvae, or ammocoetes as they are sometimes called, live in burrows in the mud and gravel in the more quiet part of the streams not far from the place where they began life as eggs. The water of their burrows contains many microscopic animals and plants, and when the lamprey draws the water into its gill chamber for respiration, the minute animals and plants are carried along. In some way, no one knows just how, a part of the microscopic life is caught or strained out of the water and passed on into the intestine for food. It is this kind of food that they live on during their entire larval life, that is, for four or five years.

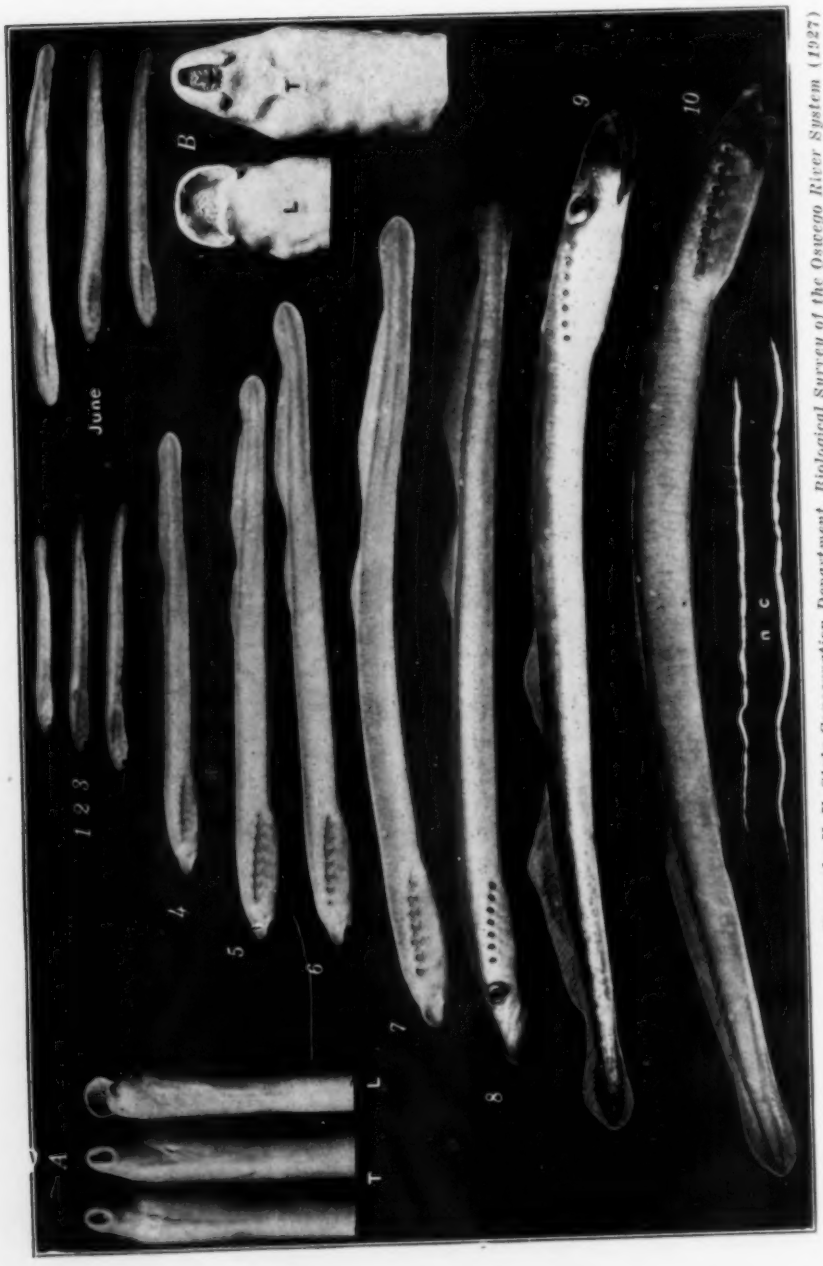
When the streams where they live get roily or turbid from rainstorms or freshets caused by melting snow and ice, muddy water drawn into the gill chamber would be likely to coat the gills with mud, and the coarser particles might fill the gill chamber after a time. To protect itself, the lamprey very long ago devised an excellent strainer in its throat. This strainer is composed of a multitude of finger-like growths from the throat wall which extend all around and cover the entire entrance with a beautiful lace work (Fig. 2: 3). This filter allows the water and the fine particles to pass through, but stops the coarser particles. After a while the strainer is liable to be clogged and thus prevent the water itself from entering the gill chamber. The lamprey learned long ages ago what to do to open the strainer. It closes the seven gill openings on each side of the neck, and then by a powerful contraction of the muscles around the neck, it forces the water back through the strainer, and this reversed stream sends the clogging particles flying.

Sanitary engineers have learned to use this method for cleaning filter beds for drinking water; that is, they reverse the current of water and allow the dirt to flow away with the reversed stream.

To see the larval lamprey clear its strainer, one of the animals is put into a test tube or slender bottle with some water made slightly milky by the addition of starch or flour. The test tube is held in a good light and the head of the animal looked at through a magnifier. A stream of the milky water will be seen passing through the strainer into the gill chamber at every inspiration. A moment later, during expiration, the milky water will be seen coming out of each of the seven gill openings along the side of the neck.

In time the strainer over the throat will become partly clogged with starch masses; then the lamprey will reverse the current and clear the strainer just as it does when the water is muddy.

It was found, when trying these experiments with the respiration, that a part of the starch grains was expelled through the gill openings with the water, but that a part of them was passed on into the intestine, which opens directly into the branchial chamber. This suggested a method of clearing the intestine of sand particles and diatom shells, which are very annoying if one wishes to make serial, microscopic sections. It suggested also that one could feed the lampreys any kind of food for experimental purposes if the food were made



From the N. Y. State Conservation Department, Biological Survey of the Oswego River System (1927)

FIG. 3. LARVAL AND TRANSFORMING LAKE LAMPREYS

1, 2, 3, GROWTH TO OCTOBER OF THE SAME SEASON. 4, 5, 6, 7, LARVAE FOSSILY OF DIFFERENT YEARS. 10, LARVA OF UNUSUAL LENGTH, DECEMBER. TRANSFORMATION THE FOLLOWING YEAR. 8, TRANSFORMING LAKE LAMPREY THAT REMAINED IN AN AQUARIUM A WHOLE YEAR IN THE LARVAL STAGE AFTER REACHING FULL LENGTH, TRANSFORMATION APPARENT IN LATE AUGUST. 9, TRANSFORMING LAKE LAMPREY FROM THE MUD-BANK, DECEMBER. JUNE, THREE LARVAE TAKEN FROM THE MUD-BANK SHOWING GROWTH IN ONE YEAR. A, TWO TRANSFORMING LAKE LAMPREYS WITH CONTRACTED CIRCULAR MOUTHS, T, AUGUST. ONE LARVA OF THE SAME LENGTH, L, WITH THE CHARACTERISTIC HOODED MOUTH, UPPER AND LOWER LIP. B, ABOUT TWICE NATURAL SIZE. L, LARVA WITH HOODED MOUTH. T, TRANSFORMING LAMPREY IN A VERY EARLY STAGE, AUGUST. N. C. NOTOCHORD OF DECAYED LAMPREY

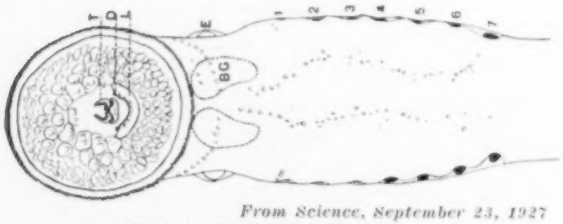
fine enough and put into the water. Many kinds of food were tried, and finally some milk was put in the water. Particles of cream and some of the milk got to the intestine. To our amazement the lamprey coagulated the milk just as a kitten or other mammal would. Probably of all the millions of generations of lampreys, this was the first time one of their number had ever had a milk diet, and yet it had a digestive ferment which served the same purpose as the rennin of a mammal (kitten, pig, etc.). As in nature the lamprey never has a milk diet, this ferment or enzyme must be for some digestive process other than the clotting of milk.

The lampreys in the mud do not have good eyes. The eyes are deeply imbedded in the tissues, but when the head is in a strong light, the eyes may be seen as small black spots beneath the skin and other tissues. This does not mean that the little lamprey can not tell when it is light, for if one of them is lying quietly in the bottom of a dish of water in the dark and a flashlight is turned on, it starts as if actually struck and seeks a shaded place. Then, too, there are sensory organs on the body which perceive the slightest movement in the water. This knowledge is very important for their safety. The fish like the little lampreys for food, as the fishermen know full well, and if the lamprey were loafing about on top of the mud in the streams he would be almost sure to be down the throat of a fish if he did not have some means of telling when danger was near. This probably explains in large part why the larval lampreys are so restless when out in the clear water, and why they bury themselves so quickly when uncovered. In their burrows they are comparatively safe, and feel more confidence in the mud than on top of it.

As all forms of lampreys begin their life in the fresh-water streams, and live in the mud for a certain time, a natural query is how long it takes them to grow up sufficiently so that they can transform to the adult stage and swim freely in the water as did their parents. No one knows the answer to that question. Just as the entomologists and every one else who deals with living forms have found, the only way to make sure with any animal is to domesticate it so far as is necessary to control the surroundings, and to watch the changes in any given individual from the egg to the desired stage. No one has ever done this with the lampreys, and therefore the time required for them to grow from the egg to the full larval size of fifteen to twenty centimeters (six to eight inches), has never been found out with certainty. Estimates have been made by collecting the larvae during every month in the year, and judging by the different sizes, or groups of sizes, how many years are represented. Judging from the different sizes obtainable at any given time, authorities have estimated that it requires about four years.

In July and August of 1898, the writer, in seeking to discover all the structural changes taking place in the transforming lamprey, collected many specimens which seemed large enough to transform. These were put into an aquarium with plenty of mud and gravel on the bottom, and with a constant stream of running water. They were dug up every week or ten days to see whether they were changing and how rapidly the change was taking place. Many of them went through the regular transformation changes, but some of the largest ones as well as some of those of medium size did not change at all, but remained in the larval stage. They were kept in the aquarium until the following July and August, and then they changed to adults in the normal way. This demonstrated that, in some cases at least, larvae of full size remain in the mud as

FORMING LAKE LAMPREY FROM THE SUCKER, *Catostomus*. *Petromyzon lamottenii* BEING FROM THE SUCKER, *Catostomus*. ONE LARVA OF THE IN ONE YEAR. A, TWO TRANSFORMING LAKE LAMPREYS WITH CONTRACTED CIRCULAR MOUTHS, T, AUGUST. ONE LARVA OF THE SAME LENGTH, L, WITH THE CHARACTERISTIC HOODED MOUTH, UPPER AND LOWER LIP. B, ABOUT TWICE NATURAL SIZE. L, LARVA WITH HOODED MOUTH. T, TRANSFORMING LAMPREY IN A VERY EARLY STAGE, AUGUST. N. C. SCORES OF DECAYED LAMPREYS



From Science, September 23, 1927

FIG. 4. LAKE LAMPREY

VENTRAL VIEW OF THE HEAD AND BRANCHIAL REGION OF A LAKE LAMPREY TO SHOW THE POSITION OF THE BUCCAL GLANDS AND THE OPENING OF THEIR DUCTS. BG. THE BEAN-SHAPED, BUCCAL GLANDS AT THE LEVEL OF THE EYES (E). T. THE RASPING TONGUE. D. THE DUCT-OPENING OF THE LEFT BUCCAL GLAND. L. THE INFRAORAL LAMINA. 1, 2, 3, 4, 5, 6, 7. THE SEVEN BRANCHIOSPORES OR GILL OPENINGS ON THE LEFT SIDE.

larvae an entire year before commencing to transform. As one can get those of full size from the mud of the streams during any month of the year, it is believed that all live an entire year in the mud after reaching full size before they commence to transform. If this is universally the case, then to the estimated four years as determined by size alone must be added a full year, making five years of life in the mud banks of the streams before transformation.

The transformation is a real one. Structures so characteristic of the larva disappear, and wholly new structures appear. The hooded mouth with an upper and under lip changes by growth into a circular disk with continuous soft edges to make the sucking mouth more perfect for clinging tightly to whatever it is in contact with (Fig. 3: A, B). The lace-like curtain for strainer over the throat disappears, and in place of the soft papillae appear sharp, horny teeth over the disk of the sucking mouth (Fig. 2: 1, 2). The rasping tongue with its savage, rake-like teeth, with powerful muscles for working the rasp, is developed. Where formerly there was a common water chamber for the gills and for the food, the seven gills on each side are enclosed in a separate pouch with an external and an internal opening. A separate tube, the esophagus, connects the throat with the intestine, instead of the intestine opening into the common water chamber for the gills, as in the larva. The eyes appear on the surface and become clear, and their retinal elements are perfected so that the sight is keen. Any one trying to catch them when freely swimming in the water will be convinced that they can see well, and the fish they attack would probably concede that the lamprey has accurate vision.

In the larva there is a gall-bladder with a duct which opens into the intestine, as in most higher forms, but at transformation the gall-bladder and gall-duct disappear so that there is no direct connection of the liver with the intestine. Still the liver grows with the growth of the lamprey. It must therefore have some important function to perform even though its direct connection with the intestine has wholly disappeared. Here is a case where nature has closed the bile duct completely without giving the lamprey jaundice, which emphasizes the fact that the production of bile for digestive purposes is not the sole function of the liver.

Many other structural changes occur, for which considerable time is required. Fortunately, as with tadpoles and caterpillars, the transforming lamprey does not take food during transformation, and therefore is easily kept in an aquarium during the whole process, so that the

time as well as the changes can be determined with exactness. Transformation may begin in the last half of July, during August, or sometimes in September. It requires from four to five months to complete all the changes, and during the time of change the young lampreys live under the mud the same as larvae.

When the organs are so far perfected that the animals can see well, attach firmly with the sucking mouth, and have developed the sharp, horny teeth on the tongue and oral disk, and the digestive canal is ready to do its work, the lampreys come out of the mud into the free water above. Naturally, after fasting from July or August to January or February, that is four to five months, the young lampreys are hungry, and on the lookout for a chance to get a good meal.

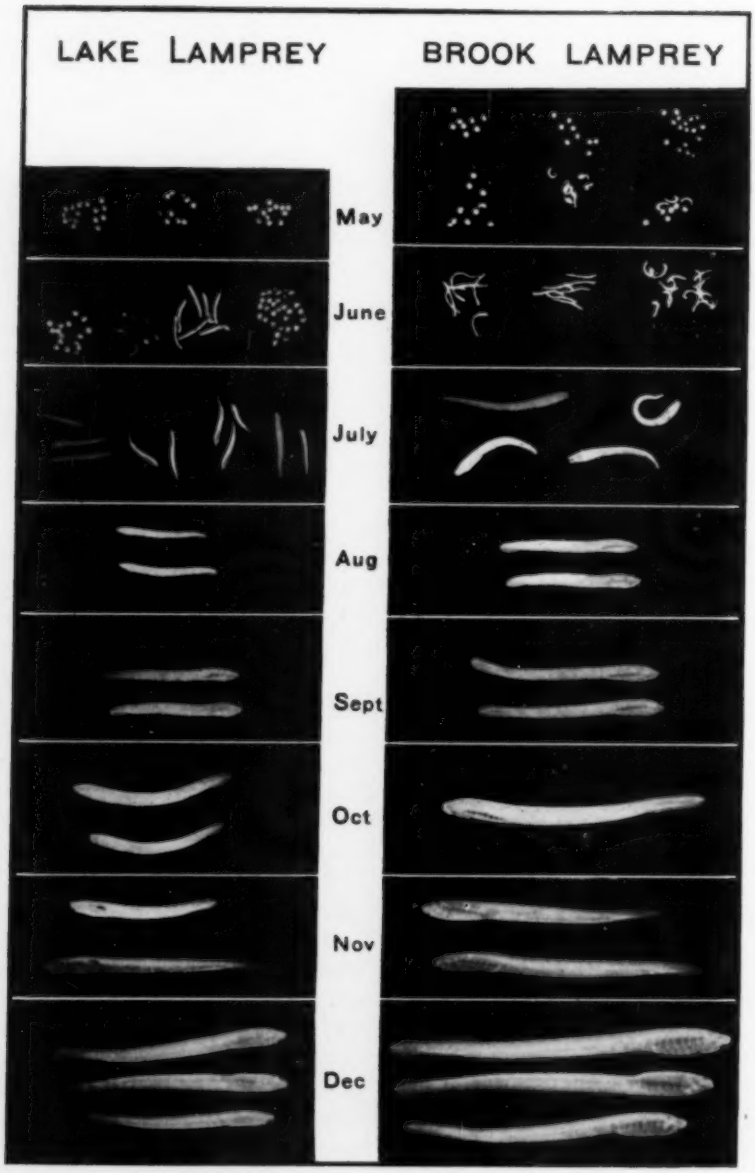
In one experiment, five of the young lampreys were ready at the same time, and they pounced upon the only fish present like a pack of wolves. They clung so tightly to the fish that lampreys and fish were transferred to a small vessel of water and all photographed together under a vertical camera. From the photograph thus obtained was made the drawing for the picture in Fig. 2: 4. Many other experiments were made with the just transformed lampreys, and they always attacked any fish available. Occasionally, if the fish was large and fierce like a pike, it turned the tables and swallowed the young lampreys whole.

In getting a meal the lamprey digs a hole right through the skin and into the muscles of the fish, and in so doing opens many blood vessels. The blood is swallowed and the minced flesh, but the main food is composed of blood. This was proved many times by taking the lamprey from the fish, or by taking lampreys freshly caught in the lake, killing them with chloroform, and then examining the intestinal contents. Much blood was always found in the intestine. That nearest the throat of the lamprey, that is, at the beginning of the intestine, was red, like recently drawn blood, and under the microscope the blood corpuscles of the fish showed perfectly. There was no chance of mistake, for the blood corpuscles of the fish are oval and thicker in the middle than at the edge, while the red corpuscles of the lamprey are circular in outline and are hollowed out in the middle like the red corpuscles of mammals.

Long ages ago when the lamprey first began to steal its food from the body of fishes, it found that the blood of fish clots very quickly when it runs out of the blood vessels and comes in contact with the wounded tissues. This is of great advantage to the fish, for otherwise it might bleed to death from a small wound. It has two real disadvantages for the lampreys: Clots are not so easy to swallow as liquid blood, and the clotting tends to close the torn blood vessels and thus shut off the food supply to the lampreys. To overcome these disadvantages, the lamprey during its transformation developed two glands (Fig. 4) on the underside of its neck near the mouth. These glands produce a secretion which, as the writer found by experiment in 1927, has the power to prevent the clotting of blood.

The glands are surrounded by voluntary muscle fibres which enable the lamprey, when it is digging the hole in the fish, to squeeze the secretion out of the gland through the duct into the mouth. Here it bathes the torn flesh of the fish and mixes with its blood as it comes out of the open blood vessels. The secretion prevents the blood from clotting, and the lamprey can get a good meal of liquid blood.

The vampire bat, the leech and probably many other blood-sucking animals have an anticoagulating secretion to prevent the clotting of the blood of their



From the N. Y. Conservation Dep't. (1927)

FIG. 5. EGGS AND YOUNG OF THE LAKE AND THE BROOK LAMPREY
SHOWING THE GROWTH FROM MONTH TO MONTH DURING THE FIRST SEASON (MAY TO DEC.). NOTE THAT THE BROOK IS CONSTANTLY IN ADVANCE. NEARLY NATURAL SIZE.

victims. No one knows what animal first devised this kind of a gland, but probably the lamprey was one of the first if not the first of all.

In order to find out how often a lamprey needs a meal, how long it remains attached to its victim and whether it always kills the fish it attacks, it was necessary to make some definite experiments. Observations on lampreys in the university aquarium revealed the fact that they are not at all bashful about getting blood from any fish in sight. If very hungry, and no other fish were present, the lamprey would even attack one of the ganoid fishes like the amia or gar pike. Following the hints got from the laboratory aquarium, advantage was taken of the abundance of fish and lampreys in the fall and winter of 1914–15 to make an extended series of experiments to answer the questions which had arisen. One of the bathtubs in the writer's home was turned into an aquarium by putting a good supply of stones of various sizes on the bottom and then adding some fish and several lampreys. To make the surroundings even more like those of Cayuga Lake, some frogs and a necturus were also put in the tub. A stream of water was kept flowing into the tub all the time, thus insuring a plentiful supply of fresh water, and making the conditions as nearly like nature as possible.

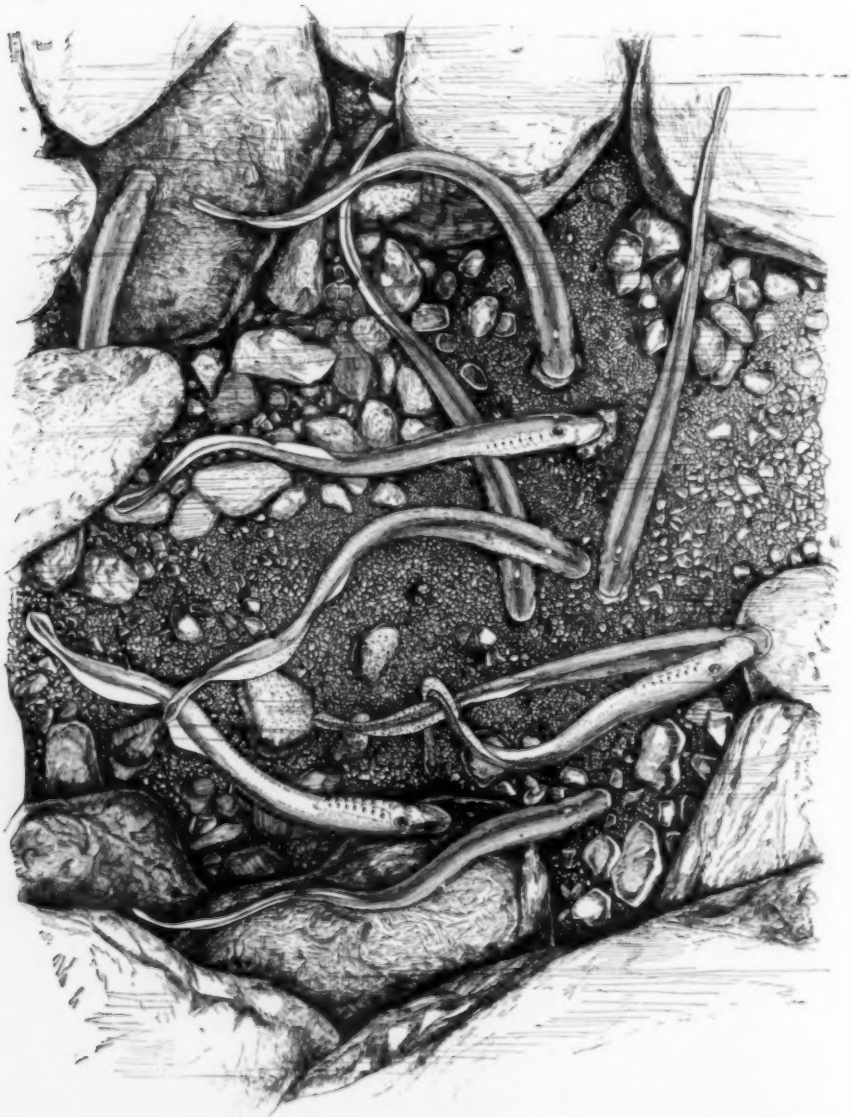
When first brought from the lake, the fish and lampreys were rather restive in the white tub, and tried to get under or behind stones. A part of the tub was covered so that there would be shade or semi-darkness. In the daytime the animals remained mostly in the shade, but at night they swam all about. If a bright light were turned on, they went back into the shaded region.

The lampreys and fish seemed wholly indifferent to one another. Often a lamprey would swim alongside a fish, or when a lamprey was attached to the tub, a fish might swim along and bump into it. This seemed strange, for chickens when they see or hear a hawk, although they were hatched in a incubator, are much agitated, and hurry for cover. Perhaps this is because in the racial history of chickens a hawk in the vicinity practically always meant an attack, while with the lampreys there is only occasionally an attack.

In watching the inhabitants of this bathtub aquarium it was never noticed that the lamprey gave any warning. When hungry it would swim around as usual, and when it got in position by the unsuspecting fish, it would turn, quick as a flash, and, bringing its expanded, sucking mouth up against the fish, stick fast. Then things happened. The fish would dash around the bathtub as if bewitched, and run up the sloping end almost out of the water. But it was of no use; the harder the fish dashed about, the tighter the lamprey stuck, as if the rapid movement had made the vacuum in the mouth even more perfect than at the beginning.

After several minutes the fish seemed exhausted and discouraged and remained quiet. The lamprey seemed to be working away to get something from the fish. The movements of the head and body reminded one of the actions of a pig or a kitten when it is sucking its mother. After some especially hard suck the fish would jump and struggle as if it hurt. Probably it did, for when the lamprey let go or was removed, there was always an ugly hole rasped in the fish (see the black spots by the fins in Fig. 1).

Many attachments were seen. The lamprey could hold fast to almost any part of the fish, but a favorite place is near the paired fins (Fig. 1). Sometimes the attachment was on the head over the eye. In that case the eye was usually dug out by the rasping tongue. This was seen in several instances. If the lamprey did not find a good supply



From the N. Y. Conservation Dep't. (1927)

FIG. 6. BROOK LAMPREY

NEST BUILDING AND SPAWNING OF THE BROOK LAMPREY FROM A DRAWING MADE AT LINCOLN PARK, APRIL 16, 1897, BY BASHFORD DEAN, ABOUT HALF NATURAL SIZE. CUT LOANED BY THE N. Y. ACAD. OF SCIENCES.

of blood in the first hole it dug, it would slide along without letting go and dig a new hole. That explains how it comes about that there are sometimes two ugly holes close together.

If the fish was large enough to supply the lamprey with a full meal of blood and have enough blood left for its own recovery, it would remain alive. However, if the fish was relatively small, so much blood was sucked out of it that it died. This was observed over and over again. That a large fish may survive was demonstrated by the bathtub experiments, and also confirmed by the testimony of fishermen who often find fresh lamprey scars on the fish they catch, and also partly healed scars.

In these experiments the lamprey remained attached to the fish about five days. After leaving the fish the lamprey attached itself to the side of the bathtub or to a stone on the bottom and remained quiet as if it knew the advisability of giving digestion a chance. The amount of blood taken at a meal was estimated by measuring the capacity of the intestine in a full-grown lake lamprey. It was twenty-five cubic centimeters (about one fluid ounce). No wonder the fish looked pale and acted so listless after being drained of such an amount of blood.

The frequency of meals for lampreys was also determined in this series of experiments. A freshly caught lamprey from Cayuga Lake, with its intestine full of blood, was put into the bathtub with various kinds of fish. The lamprey remained content for about a month, then it attacked a bullhead (Amiurus). It remained attached for five days, and then let go of the fish and attached to a stone on the bottom. The same day the lamprey was taken to the laboratory, killed with chloroform and examined. The intestine was full of blood, which under the microscope showed perfectly the blood corpuscles of the bullhead. From this experiment, then, it is concluded that the lamprey requires a full meal of blood about once a month.

The time required for a lake lamprey to attain full size has never been determined. Judging from the different sizes taken in Cayuga Lake at all seasons of the year, it can not be less than about two years, and is more probably three or four years. The lake lamprey (Fig. 3:5) increases in length from about fifteen to twenty centimeters (six to eight inches) to a length of thirty-five to fifty centimeters (thirteen to twenty inches), that is, it increases two to three times in length. In weight it increases twenty-five to thirty times. One can get some idea from these figures how much fish blood is required for this growth during the two to four years of life in the waters of the lake. With the large sea lamprey the increase in length is from fifteen to twenty centimeters up to seventy-five to one hundred centimeters, and the increase in weight is about one hundred times. It must take a lot of fish blood for all that growth!

Some years as many as a thousand lake lampreys have been caught in the streams entering Cayuga Lake during a single spawning season, and even a greater number from the streams of Seneca Lake. These figures give a clue to the possible damage to the food fishes of the lakes during the two to four years of the predatory life of the lampreys. Observations upon the fishes caught in the lakes have fully confirmed the supposed damage.

No matter where the lampreys may live in their adult stage, whether it be brook, lake or ocean, when mature, they all go back to the fresh-water streams where they started life, or at least to similar streams, to lay their eggs for a new generation. To get to those places the lampreys may have to swim hundreds of miles and overcome many obstacles; for example, when they pass from the

ocean through Delaware Bay and up the Delaware River to the streams in the Catskill Mountains. Those in the Hudson and the Susquehanna may have to swim as far or even farther, and those in the Pacific Ocean may have to make even a longer journey up the Columbia River and into its headwater tributaries. Those from the Great Lakes and the Finger Lakes do not have to go so far. As can be easily imagined, they are liable to meet many obstacles in these migrations, as do the salmon and other fishes that ascend fresh-water streams to deposit their eggs. All of them show great persistence and often much ingenuity in overcoming the difficulties in the way. From those kept in aquaria in the laboratory during the spawning season (May and June) have come unbelievable feats in their efforts to escape and find the stream they were in search of when caught. To prevent their getting out of the aquarium, overhanging ledges were put all around the edge, but some of them got out even over the ledges. It seemed impossible, but some of them accomplished the feat.

It is told of those going up the Columbia River that they climb the rocks in the steep places by successive leaps, hanging on by their sucking mouths every time in order not to lose any of the progress made. After observing them under many different conditions one can believe almost anything about them.

One very striking, almost human, feature in the sea and the lake lamprey is the brilliant wedding costume they put on as they go up the streams to spawn in May and June. Instead of the modest gray and black of ordinary life, many of them of both sexes become gorgeous in bright orange and black. Sometimes the males are most brilliant and sometimes the females, and often both are equally arrayed, and in the clear waters of the spawning streams they make a very striking and handsome appearance. Not all are dressed up so gaily, for some seem to be satisfied to go in the plainest attire. The coloring is also more brilliant some years than others.

Finally, having overcome all difficulties, and having reached a favorable location where the water is moderately swift and where there is a gravelly bottom, they proceed to make a nest. Often the male precedes the female, and in that case commences the nest alone, but when the female comes along she helps with might and main. The nest is built in this way: From the middle of the place selected, the larger stones are grasped by the sucking mouth, jerked loose, and carried (Fig. 2: 7) or pulled along the bottom down stream some distance and dropped. This goes on for some time until a washbowl-shaped excavation has been made, and there is plenty of fine gravel and sand in the middle of the nest. it would be gratifying to be able to say that when a stone is too big for one of the lampreys the other turns to and helps; but while the writer has watched the building of hundreds of nests, he has never seen two lampreys pulling the same large stone, although if they did pull together, the large stone might easily be moved.

When the nest is far enough along to have an edge of stones and plenty of sand in the middle, the egg laying begins. For this the female attaches herself to a large stone and the male attaches his mouth to the side or top of her head (Fig. 6). Then they curl their tails down to the sand and stir up a great cloud of it. At first it was not easy to see the advantage of stirring up a cloud of sand during the egg laying, but by a little study and observation the reason became clear. As stated above, the eggs are laid in the stream where the water is rather swift, and the current would be liable to carry the tiny eggs down stream if there were not some means of preventing it. The means of

prevention is this: In the ovary a thin layer is put upon the outside of the egg. This covering, becoming very sticky just as soon as it gets into the water, serves to stick the egg to any solid body it comes in contact with. The cloud of sand stirred up by the tails of the lampreys is composed of a multitude of little stones to which the eggs stick and are carried by the heavy stones to the bottom, and thus prevented from going down stream with the current.

If one looks into a nest immediately after a batch of eggs is laid, every egg will be found sticking to a stone. To make sure that the eggs are not exposed to danger of any kind, just as soon as a period of laying is finished, the lampreys commence to pull the stones from the upper part of the nest. This loosens the sand, which is carried down into the nest by the current, and covers the eggs so that, in a short time, none are visible. Safely covered by the sand, the sticky character of the outer coating soon disappears, and the eggs become free among the sand grains and little stones in the middle of the nest.

In a few hours the eggs commence to develop, and in a few days, depending on the temperature of the water, the little lampreys hatch and wriggle about among the fine stones in the nest. They stay in the nest until all or nearly all of the food-yolk that their mother put into the egg for them to start life with has been used up. Meantime their heart, blood vessels, a mouth, gills and a digestive tube have developed, and they are ready to take food from the water. It takes about three weeks for all this and many other things to happen. At this time they are about as slender as a pin and about one centimeter long. Their muscles are well developed, and they are quick as a wink, so that it is difficult to catch them.

From the nest they wander in search of a mud-bank in the stream where they will not be so crowded and where there is an abundance of microscopic life in the water to supply them with food.

The parent lampreys, after the egg laying, stay about the nest for a few days, occasionally pulling some of the stones from the upper edge and thus loosening the sand which flows down with the current and covers the eggs still deeper. The life-work of the parents is now complete. The journey, the nest building, egg laying and their long fast have exhausted them, and they soon die. Formerly it was believed by some that they returned to the lake, or to the ocean, if sea lampreys, took food again and recuperated, and got ready for laying another crop of eggs the next year.

We know now that there are no minute eggs in the ovary to grow and produce a second generation, and that the lampreys all die in the streams and never return to the lakes or to the ocean. But as the lake lamprey lays approximately a hundred thousand eggs, and the sea lamprey two hundred and fifty thousand, the continuation of the race is pretty well safeguarded.

As the lampreys have no bones, no bony teeth, and only a few cartilages and some soft tissues for a skeleton, one can see why the remains of the dead lampreys are so seldom found, especially two or three weeks after the spawning season. Curiously enough, however, while there are no bones to persist after the soft parts have decayed, and thus leave a record, there is one part of the lamprey which is quite persistent. It is the notochord, which represents the primitive body axis, vertebral column or backbone. Those first found (Fig. 3: n. c.), were a great puzzle. As shown in the picture, they look like slender worms or snakes. Their origin was determined only by finding decaying lampreys with the notochord partly in place, and then by macerating lampreys in the laboratory. If a paleontologist were to find a fossil notochord what would he call it?

FIG. 7. BROOK LAMPREYS (NATURAL SIZE) *From the N. Y. Conservation Dept. (1927)*

(1) FEMALE WITH EGGS SHOWING THROUGH ABDOMINAL WALL. DARK SPOTS ALONG THE SIDE SHOW WHERE MALE HAD ATTACHED HIS SUCKING MOUTH. (2) MALE SHOWING ELONGATED GENITO-URINARY TUBE. (3) SPENT FEMALE FROM THE SPAWNING GROUNDS IN MAY. SECOND DORSAL FIN SHOWS POSITION OF OEDEMA AND SCARLET SPOT.

Up to 1897–98 the belief was universal that all lampreys were parasitic in their adult life. They all have the sucking mouth and a rasping tongue, and nearly all of them have horny teeth scattered over the oral disk.

In 1897 the author collected many of the large larvae in July and August to get the different steps in the transforming period. Some of the larvae proved to be brook lampreys. As stated above, when the lake lampreys emerged from the mud in January or February, they attacked with great ferocity any fish present. When the brook lampreys emerged from the mud into the free water of the aquarium, they paid no attention to the fish present, but attached themselves to stones in the bottom or to the sides of the aquarium.

Back in 1890–93, the writer found that the brook lampreys in the adult stage were no longer than the largest larvae, and sometimes even smaller. It was found also that the eggs at transformation are nearly as large as when laid a few days or weeks later. On the other hand, the just transformed lake lamprey is only about one third as long as the adult, and the eggs are very minute. It was noticed also that when the just transformed brook lamprey attached to the side of the aquarium and hung down, that the large eggs showed through the thin abdominal wall. Brook lampreys from the streams at the same date showed the eggs through the body wall the same as the one in the aquarium (Fig. 2: 5; Fig. 7: 1). It was concluded, therefore, and abundantly verified during the next ten years, that the brook lamprey of New York State is never parasitic, that its free swimming life is only long enough to find the spawning grounds, build its nest, lay its eggs and then die. It is now believed that this is true of all the small brook lampreys all over America, and indeed in the whole world.

This brings up a profound biological question. All are agreed that parasitism is an acquired habit and not the original mode of life of any form, and as no lamprey is parasitic in its larval stage, the parasitic habit must have been acquired in the adult stage. The sea and the lake lamprey have retained the parasitic habit; but how explain the sucking mouth, rasping tongue and even the anticoagulating glands of the brook lamprey? Without doubt the brook lamprey was also parasitic at one time, but it lost the parasitic habit—reformed, so to speak. Not now being parasitic at any time of its life, it does not need to go to the larger waters of the lake or ocean, but remains during its entire life-cycle in the fresh-water streams where it began life, and where in turn it will lay eggs to continue its race. This is believed to be true of all brook lampreys wherever found.

Some of the brook forms, especially those of the Ichthyomyzon group, have apparently gone further in returning to the non-parasitic condition than most brook lampreys, in that they have lost most, and in some cases apparently all, of the horny teeth both on the rasping tongue and on the oral disk. That is, perhaps they gave up the parasitic habit earlier in geologic time.

In trying to read backward the racial history of the brook lampreys it seems possible, and perhaps probable, that they lived a parasitic life for unnumbered ages. Then for some reason their adult parasitic life became more and more difficult and grew shorter and shorter, until finally—perhaps in the glacial period—parasitism was given up, and the free life in the open water was only long enough to enable them to find a suitable spawning place, build their nests and lay their eggs. At any rate, that is their life history at the present time.

At the end of this story the reader might fairly ask, as scientific men some-

MAY. SECOND DORSAL FIN SHOWS POSITION OF OEDEMA AND SCARLET SPOT.

times ask themselves: "What is the good of studying lowly forms like lampreys when there are so many migher forms about which much is yet to be learned?" Those over seventy can well remember the time when men peering into a microscope day after day studying the minute forms of bacteria and protozoa were looked upon with good-natured contempt as having something wrong with their "upper story." And many who are younger can remember how foolish it once seemed to most people that mosquitoes have anything to do with malaria or yellow fever! Now every one knows that the minutest animal and plant forms may exert the greatest possible influence upon human life.

It is not claimed or suggested that the lampreys have so vital a relation to human welfare. They do have some relation, for the large sea lampreys on their way up the rivers and streams to spawn make excellent food for human beings, and the young lampreys from the mud make the best kind of bait for fishing. The adult lampreys of the Great Lakes and of the Finger Lakes of New York are destructive of the food fishes. It is evident that if any wise attempt is to be made to eliminate them, their full life history must be known, and advantage taken of any weak spots in that history. No one would think it practicable to dig up all the larvae in the mud-banks. It would be equally futile to try to catch all the adults scattered throughout the waters of the lakes. But as all the adults go up the streams to spawn at approximately the same time, they become concentrated, so to speak, and then it would be possible to catch and destroy them on their way, thus preventing the eggs from being laid for a new generation.

After all, however, the purely economic advantage to be gained from a knowledge of these lowly animals is not enough to inspire laborious experiments and study throughout long years. The real impelling ground for such investigations is the desire to know for its own sake, and the hope that by the study of simple forms there will come to light some of the underlying principles which determine living structure and action—principles which in the end may help in the understanding of the more complex structures and functions of the higher forms and, finally, of human beings.

Perhaps the thought the author is trying to convey as to the underlying reasons and explanation for the zeal with which investigations are pursued may be clear to many through the medium of poetry:

> Flower in the crannied wall,
> I pluck you out of the crannies—
> Hold you here, root and all, in my hand,
> Little flower—but if I could understand
> What you are, root and all, and all in all,
> I should know what God and man is.
>
> —*Tennyson.*

> As with fingers of the blind,
> We are groping here to find
> What the hieroglyphics mean
> Of the Unseen in the seen,
> What the thought which underlies
> Nature's masking and disguise,
> What it is that hides beneath
> Blight and bloom, birth and death.
>
> —*Whittier*, in "Agassiz's Prayer."

SOME OF THE SCIENTIFIC PROBLEMS OF TANNING

By Professor GEORGE D. McLAUGHLIN and Dr. JOHN H. HIGHBERGER
RESEARCH LABORATORY OF THE TANNERS' COUNCIL, UNIVERSITY OF CINCINNATI

WITHIN the last two or three decades a fund of knowledge has been growing up, in part transferred and applied from other fields, in part amassed by patient workers within this particular one, which to-day constitutes what we know of the particular sphere of scientific effort which is called "leather chemistry." This, as its name implies, comprises the study of the phenomena occurring during the transformation of animal skin into the non-putrescible material called leather. Probably few people realize that what occurs during this process presents, for the investigation of the leather chemist, a set of problems which are as complex, and, for the most part, as little understood as are to be found anywhere. In order to be impressed with the truth of this statement, the reader need only consider those two great fields of organic chemistry with whose progress the art of leather making is so very closely bound up—the animal proteins and the vegetable tannins, the foundation stones of our knowledge of both of which, curiously enough, were laid by the patient effort of the same great chemist—Emil Fischer. And while the modern leather chemist is sometimes given to understand that the alleged "applied" nature of his work is beneath the dignity of the "pure" scientist, yet consolation is found in the fact that the field of tanning has interested men such as Fischer, to whose name may be added those of Lavoisier, Humphrey Davy, Berzelius, Dumas and Liebig. It is also pertinent to reflect that two of the pioneers in the newer conceptions of the molecular structure of the proteins are the leather chemists, Stiasny and Bergmann, and that the entire work of Jacques Loeb on colloidal behavior—disappointing though it has since proven—was based upon the earlier investigations of the two leather chemists, H. R. Procter and J. A. Wilson.

The laws which underlie the chemistry and physics of living and of dead animal skin are of interest to a widely diversified group. The medical worker attaches importance to the skin's form, structure and function and he is learning that skin disorders are usually symptomatic of still more important disturbances of other organs or of body processes. Those physiological chemists who have considered the subject recognize the usefulness of skin as experimental material because of its close relation to other animal tissues, and rejoice in the fact that excised skin changes in composition less rapidly than do many other excised tissues. The great bulk of the experiments performed in the problem of the hydration and dehydration of tissues and other organic colloidal material have been made with gelatin—a skin derivative.

Animal skin is thus of interest to the scientist if only by reason of its great usefulness as an experimental material in the investigation of colloid chemical problems, but it also possesses a greater and more intrinsic interest in its structure and composition, which we shall describe briefly, and follow by a discussion of that curious and interesting

phenomenon which the tanner terms "unhairing." Although we shall confine our remarks in particular to the skin of the steer, they may be applied in a general way to almost any animal skin.

Histologically, skin may, for the present purpose, be divided into the epidermis, the corium and the fleshy adipose layer which connects the skin to the underlying body. The hair or wool is held in a pocket or follicle which dips down into the skin below the surface epidermis; the depth of the follicle's penetration varies with the type of animal. The inner lining of the follicle which holds the hair is a downward extension of the epidermis. In the upper portion of the skin are found the fat and sweat glands together with elastin fibers, nerves and the erector pili muscles, one of which is attached to each hair. It is the contraction of this muscle which causes the appearance of the phenomenon called "goose flesh." Distributed throughout the entire skin are to be found blood vessels.

The corium—which composes the bulk of the weight and thickness of the skin—is made up of interlacing bundles of collagen fibers. These bundles are bathed in a lubricating and cementing protein (or mixture of proteins) which is of the coagulable type. The corium contains few fat cells or elastin fibers, although it is plentifully supplied with blood vessels.

The adipose layer is composed of tissue, fat cells and muscle, and is well supplied with blood vessels.

When skin is examined chemically, it is found to contain the four great classes of substances which characterize all animal tissues—proteins, fats, carbohydrates and mineral salts. Of these it contains about 35 per cent. protein, 1 per cent. fat, 1 per cent. mineral matter; with only traces of carbohydrates, together with about 60 per cent. water.

The proteins, of course, are the basis of all living tissue, the substances which seem to be most closely concerned (if any one class of substances may be said to be so more than the others) in the chemistry of the vital processes. In the representatives of this family which are found in skin we have an interesting example of the ability of nature to adapt materials to external conditions. The proteins of those tissues where the metabolic rate is highest, and which are protected from external influences, such as the blood, cardiac muscle, etc., are extremely complex and extremely sensitive to changes in physical and chemical conditions. Slight changes in reaction alter them in some way, slight increments of heat coagulate them and change them entirely, and it is very doubtful whether the proteins of this type which the chemist isolates for examination are the same entity in his test-tube that they are in their natural environment. Since the principal function of the skin, however, besides the rôle it plays in respiration and the removal of body wastes, seems to be one of protection to the more delicate tissues, which it serves as a kind of armor, the molecular architecture of its main protein constituents has been altered in such a way as to make them rather resistant materials. The chief proteins of the skin belong to that class which are called by American biochemists "albuminoids," and by their British confrères the "sclero-proteins," that is, the hard, or tough proteins. As to what is the nature of the difference between the skin proteins and other proteins, which gives them their distinctive properties, we are still very much in the dark. With one or two exceptions they are built up of the same amino acids, so that the difference is evidently due to a different arrangement in the molecule of these "building bricks," as the Germans call them. One hypothesis holds that

instead of the simple open-chain structure which is generally assumed to exist in the ordinary proteins, these albuminoids are built up of the amino acids linked in heterocyclic rings, or double anhydrides. Many of these anhydrides of the simple amino acids have been prepared, and they are found to be extremely insoluble substances, quite resistant to hydrolysis, which lends some support to the idea.

The albuminoids which are found in skin are keratin, collagen and elastin. Keratin is a more or less generic term which probably embraces a number of similar proteins. Thus the proteins of the hair and of the epidermal layer are both called keratin, and yet there is considerable difference between them. The chief chemical characteristic of the keratins, apart from the properties already mentioned, is their relatively high content of the amino acids cystine and tyrosine. Cystine was until very recently the only sulphur-containing acid known to exist in the proteins, and the keratins are thus distinguished by their larger content of sulphur.

Collagen forms the bulk of the protein present in skin, and the corium consists almost entirely of it. It represents about 33 per cent. of the total weight of the skin, and is the material in which the tanner is chiefly interested, since it is the substance which combines with the tanning agents to form leather. The name collagen literally signifies "glue-former," as the protein is changed on boiling with water or dilute acids into glue or gelatin. For this reason it has been suggested that collagen is the anhydride of gelatin, but as to its actual molecular structure we know no more than we do of the other proteins.

Elastin is a peculiar type of protein, which, as its name suggests, is the essential component of elastic tissues. It is present in the skin to only a small amount.

Proteins of the heat coagulable type—albumins and globulins—are also found in the skin to a very small extent. As has been mentioned, their function seems to be that of a lubricating and cementing mixture for the bundles of collagen fibers.

The carbohydrates occur in skin only in traces, and there is some evidence that they are present as compounds similar to glycogen.

The fatty material of the corium, except for a somewhat lower saponification value and the presence of an appreciable quantity of lecithin and cholesterol, has approximately the same characteristics as beef tallow. Only a portion of this fat is in the free state, as is evidenced by the few fat cells to be found in the corium; most of it seems to be in some sort of combination, which may be broken and the fat freed by the action of acids or of proteolytic bacteria.

The mineral matter of skin represents about 1 per cent. of its weight. The principal elements present are sodium, calcium, iron, magnesium, phosphorus and silicon. There are undoubtedly many others present in traces, but these have not yet been determined.

The Unhairing of Skin

All skin which is made into leather (except furs) must first be dehaired. That is, the entire epidermis (including both that on the free surface and that lining the follicle) must be decomposed, enabling the hair and the now disintegrated epidermal material to be mechanically removed, together with the fleshy adipose layer. This epidermal disintegration is accomplished by a process that has been employed for many centuries which consists in soaking the skin in a saturated solution of calcium hydroxid until the desired decomposition of the epidermis has been attained. Any alkali will bring this change about but lime is the most desir-

able, because of its limited solubility and its cheapness. Also, lime dissolves less of the underlying corium than do most other alkalies. It is general practice to use the same lime solution a number of times before discarding it, since it was early found that such a practice caused the lime solution to act more rapidly and effectively upon the epidermis. Curious anomalies arose in the tanner's unhairing practice; no two reused lime solutions acted exactly alike, nor did any two skins exhibit similar behavior—hence the impossibility of operating according to any rule.

For some fifty years leather scientists attempted unsuccessfully to understand the fundamental mechanism of unhairing and to answer the questions: (1) Is the process a purely chemical one, or are the bacteria and enzymes carried into the lime solution by the always partly digested skin necessary for the lime's action? (2) What is the reason for the "mellow" or reused lime solution's behavior towards the skin, compared with fresh or non-mellow lime? (3) How is this mellowness brought about?

Earlier studies failed to solve these problems because investigators were either chemists or bacteriologists, limited by the special knowledge of their special science. The answers were found only when chemists and bacteriologists attacked the problems simultaneously and cooperatively. A brief description of their work follows.

Examination showed that typical skin bacteria were unable to live more than a few hours in the presence of saturated lime; that only spore formers survived and that a very old, mellow lime (through which many lots of skins had passed) contained very few bacteria and even these were not active. And, in addition, it was found that sterile skin was easily unhaired by sterile lime solution. Further experiment proved that the skin enzymes were inactivated by saturated lime in from fifteen to thirty minutes.

With the elimination from the field of both bacterial and enzymatic agencies, it became evident that the liming process was, therefore, of a purely chemical nature. And it was found that the chemical reaction between the skin epidermis and lime may be followed quantitatively by the amount of sulphur dissolved in and by the lime solution. This sulphur is derived from keratin, the protein of the epidermis which, as already mentioned, contains the amino acid cystine ($HOOC \cdot CH(NH_2) \cdot CH_2S - SCH_2\ CH(NH_2)COOH$. As the cystine is broken down sulphur is liberated and dissolved and unhairing will not occur until this dissolved sulphur value reaches a definite minimum for any given skin. The time required for unhairing may be shortened by raising the temperature of the lime solution or increased by lowering the temperature, but, at the point of unhairing, the dissolved sulphur values are found to be the same, regardless of temperature.

Proceeding to the second question: the reason for the mellowness of reused lime solutions. Here again the possible rôle of bacteria and enzymes, as well as of the ammonia dissolved in the lime solution due to bacterial digestion of the skin before it entered the lime, were considered to be possible contributing factors. Yet practice showed peculiar anomalies: supposedly mellow limes were not always mellow and behavior in liming often varied from skin to skin. Nor could the amount of ammonia present be taken as either an explanation for nor as a measure of mellowness, while bacteria and enzymes—as shown above—were eliminated. It was finally found that the mellowness or lack of mellowness of a lime solution was due to the presence or absence of primary amines. If a primary amine, methyl amine for

example, is added to an unused lime solution a "mellow" lime results. Further experimentation has indicated that the action of the amine is probably one of catalysis of the decomposition of the keratin, which explains why the quantity of amine present in mellow limes may be extremely small and yet so markedly affect the speed of reaction between the lime and epidermis.

The third question—the source of the amine—was next answered. If freshly flayed skin (where bacterial digestion is practically absent) is passed through the lime, little or no mellowness results. If, on the other hand, the proteolytic bacteria present upon the skin are allowed to digest it, mellowness in liming will result. The greater the extent of bacterial digestion the mellower will be the lime. In other words, the amine is formed by bacterial digestion of valuable skin proteins. This may be illustrated by the action of certain proteolytic bacteria upon one of the skin amino acids—glycocoll—which is, by them, decomposed into methyl amine and carbon dioxid: $CH_2 \cdot NH_2 \cdot COOH = CO_2 + CH_3NH_2$.

A scientific understanding of the materials and processes of tanning is of vital importance to the industry, since such knowledge must underlie all advances in the methods of manufacture and the production of more and better leather from a unit of raw material. This is of especial importance at the present time because the world's population of animals whose skin may be used for leather has not kept pace with the increase of its human population. And fundamental knowledge gained in the science of the tissue skin and the materials with which it is tanned can not fail to be of value in the field of so-called pure sciences.

FALLING WATER

By Professor O. D. VON ENGELN

CORNELL UNIVERSITY

> And dashing and flashing and splashing and clashing;
> And so never ending, but always descending,
> Sounds and motions for ever and ever are blending,
> All at once and all o'er, with a mighty uproar,
> And this way the Water comes down at Lodore.

THUS wrote Southey to please his children, who demanded a poetical description of the waterfall they knew. Although the form of the versification is such that even the authors of guidebooks venture to indulge themselves in literary criticism by referring to the "jingling rhymes," it is nevertheless true that "The Cataract of Lodore" is most remembered of Southey's pieces. Its jingling rhymes give expression to sensations that not only those of tender years, but grown-ups as well, experience when standing beside a waterfall.

Water in any form, a brook, a river, a lake, the sea, gives charm to the landscape in which it appears. There is a suggestion of cool depths. Beautiful reflections are caught in the water mirror. One is attracted to boating over the limpid surface. These ideas are not commonly put into words but they are nevertheless present in the background of consciousness. But we go deliberately to places where water comes to life, runs, foams, leaps and pours over rocky brinks; plunges and disappears into the depths of shadowy glens. There we anticipate music and mystery, potency of motion in a ceaseless rush.

Our interest in waterfalls would probably become merely passive, however, if these offered nothing further than the spectacle of a tumbling stream. A visit to one or two waterfall sites would satisfy curiosity. Instead of such a reaction we note that the prospect of a visit to a new cascade quite invariably gives anticipatory pleasure, pleasure which is enhanced by realization. We may very properly inquire why such active interest should continue to possess us, whereas we so easily become indifferent to other aspects of scenic beauty.

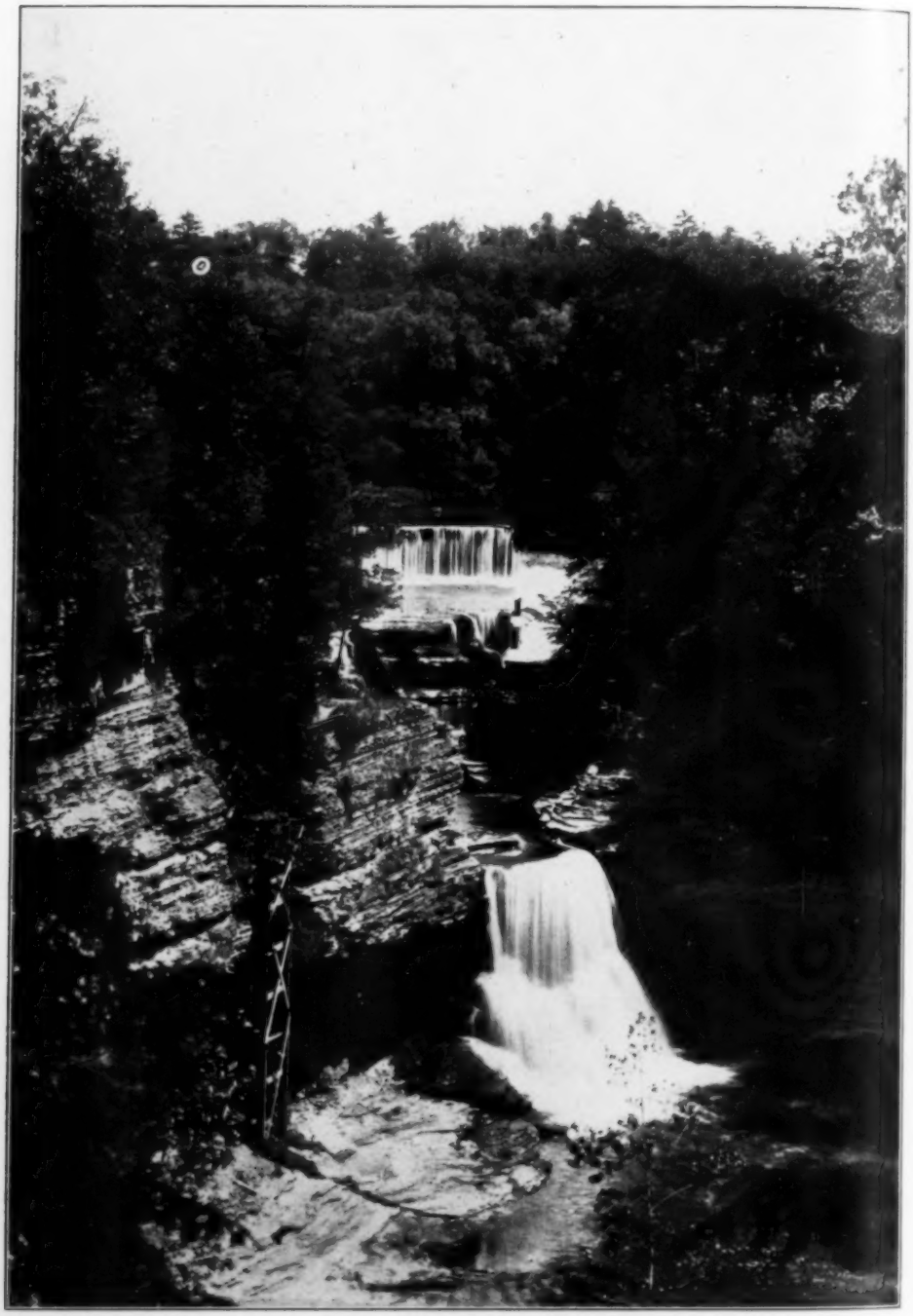
The answer to this question, stated concisely, is that the form and setting of the falls attract us as much or more than does the tumbling water. In the first place there are several great classes of waterfalls. Each of these classes has a distinctive aspect. One who travels widely and sees waterfalls in many regions will become aware of these greater differences. But in any given district numerous waterfalls of a single type will each one be unique in the details of its form. There will be all gradations in volume from a Niagara to a woodland brook. And where water falls, it is from a rocky brink that it leaps, and into a rock-walled depression that it plunges. According as the nature and the structure of the rock vary, there can be significant large differences of form and a thousand differences in details in one general type of waterfall. It is the infinite variety in waterfalls that makes their appeal unfailing.

Once this fact is appreciated we begin to wonder about the origin of waterfalls and seek to know the cause of each variation in aspect. And if we can learn to read the answers to these questions we become even more anxious to visit new waterfall sites, for it is found that each example illustrates a new phase of the general story.

Waterfalls develop most commonly where a stream first encounters very resistant rock in its course and then flows

TAUGHANNOCK (TAGHANIC) FALLS, NEAR CAYUGA LAKE, NEW YORK

TAUGHANNOCK FALLS HAS NO CONSPICUOUSLY STRONG CAP ROCK, HENCE NO EAVES, BUT THE MARKED DEVELOPMENT OF JOINTS AND THE READY YIELD TO WEATHERING OF THE SOFT GENESEE SHALE BELOW THE CREST HAS PERMITTED THE PRONOUNCED SPRAY EFFECT (PARTIALLY SHOWN IN THE PICTURE) TO OPEN A WIDE AMPHITHEATER BELOW THE FALLS.



TRIPHAMMER FALLS, FALL CREEK, NEW YORK

HERE THE EFFECTS OF THE TWO TYPES OF WATERFALL RECESSION APPEAR IN ONE PICTURE. THE UPPER FALLS ARE RECEDING, LIKE NIAGARA, DUE TO PLUNGE POOL GRINDING; THE LOWER FALLS RECEDE IN PART BY PLUNGE POOL GRINDING, IN PART BY WEATHERING WITH OVERHANGING EAVES, THUS GIVING RISE TO AN AMPHITHEATER.

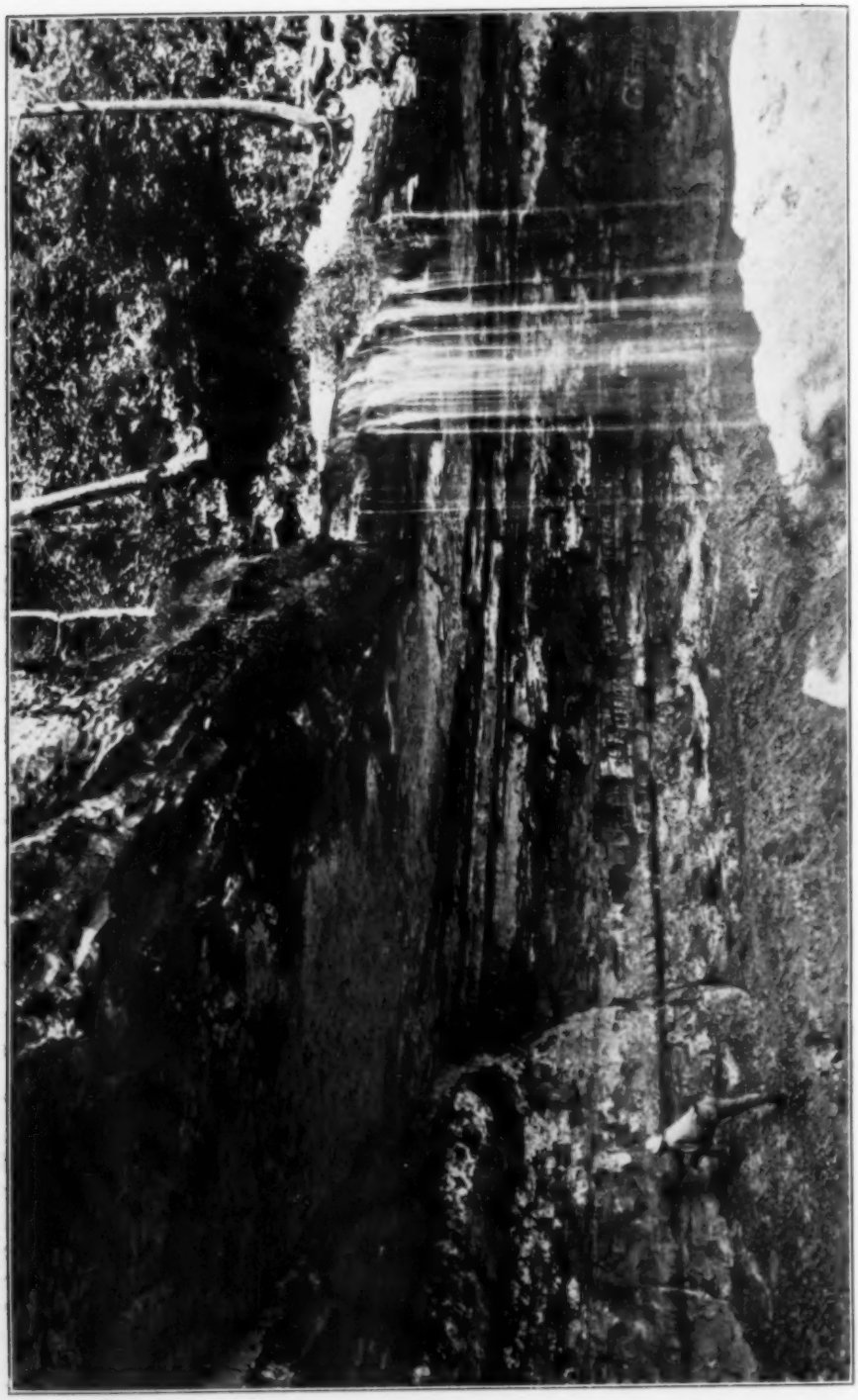
over weak rock that is easily and quickly rubbed away. Niagara is the greatest exhibit of this type. The abrasion wrought by the sand and silt carried along by the current only very slightly affects the durable rock upstream from the waterfall site. But the same current passing over the weak materials downstream very quickly scours out a deep channel. Then a waterfall comes into being where the strong rock ends and the weak rock begins. Once started the falls perpetuates itself, indeed it tends to make the falls effect more pronounced as time passes. The water now plunges on the weak formation when previously it had only flowed over it. Above the falls the strong rock continues to be only slowly worn by current scour.

But even where a falls is made progressively higher by the always more rapid rubbing away of the weak rocks downstream the durable rock at the brink of the falls does not escape all destruction. The pounding of the water at the base of the falls tends to excavate a pool at that point. As this pool is enlarged laterally it undercuts the strong rock. When such undermining has proceeded to a condition that deprives the crest rock of adequate basal support pieces of the durable ledge at the brink of the falls break off. Such pieces are seized upon by the churning waters in the basin below the falls and whirled about. Thus boulders from the brink become tools used to accelerate the undermining process. In consequence of these conditions the crest line of the falls may be caused to recede upstream at a surprisingly rapid rate.

In our literature of national humor, Niagara, the majestic, is journey's end of the newly wedded only. In fact, however, Niagara as the outstanding example of the strong rock-weak rock, horizontal layer type of waterfall always has attracted thousands of other visitors, persons of consequence and of no consequence, besides bridal couples, and no doubt always will be a goal for legions of sightseers. Niagara is also representative of one extreme in aspect that this type of waterfall shows. At Niagara the volume of water going over the crest is tremendous; the supply unfailing. Night and day, year in and year out, in unvarying quantity those thousands of tons of water per second hurl themselves over Niagara's brink. The undermining effect is extraordinarily rapid in its action. Within historic time the crest of the falls has been noted to go back hundreds of feet. The measured rate of recession at certain points along the crest is over five feet each year.

In consequence of these conditions one sees at Niagara a river flowing almost on the surface of the land above the falls, a heavy curtain of water going over the falls, and downstream a gorge seven miles long with nearly vertical walls of rock on both sides for all its length.

This gorge is the significant feature of the Niagara waterfall occurrence. We are led to inquire why the gorge valley below the falls should here be so prominently developed. The answer is that the rapid recession of the crest of the falls that we have been able to note and measure within historic time has been going on practically uninterruptedly since the time when the falls first started at Lewiston. So rapid is the recession that the processes of weathering: frost, rain, solution and decay, which are competent to cause marked roughening of stone, polished by man for monumental purposes, within a few years, have not effected enough crumbling to cause the gorge walls to lose their cliff form in any part of the gorge in the time since the recession of the falls first gave them existence. To-day the rocks of the gorge sides stand quite as straight-walled, steep and bare as when the falls crest passed each point of the length of the gorge in its hurried recession.



TINKERS FALLS, LABRADOR HOLLOW, NEW YORK

HAS BIG OVERHANGING EAVES. THERE IS A WIDE, DEEP, STEEP-WALLED AMPHITHEATER IMMEDIATELY BELOW THE FALLS.

For the other extreme in form let us look at a falls which is as obscure as Niagara is well known. At Tinkers Falls, Labrador Hollow, in central New York, we find only a slender stream, a woodland brook pouring its waters over a rocky crest. The same conditions of rock arrangement that exist at Niagara prevail here also: the strong rock on top, the weak rock below and horizontal layering. But what a difference in waterfall aspect! It would almost seem that this falls had planned to feature its rocky setting in a big way in order to compensate for its punier volume. It shows its cap rock boldly and distinctly making clear how strong it is. All Niagara's cap rock is hidden at the falls. Then it makes up for a long steep-sided gorge by producing a great amphitheater beyond and around the falls. It causes the cap rock to overhang as tremendously wide eaves so that one can go behind the falls and look at the falling curtain of water in front.

The site seems so completely sheltered from storm and wind that a primitive family might be expected to select it for a home place. Such a family could dig itself a roomy cave into the soft rock underneath the cap rock of the falls, build a fire on the sheld in front of the cave and let the rest of the world go by. But as a permanent residence such a place would have its disadvantages. It looks well on a sunny day. It even makes a fascinating retreat when one is caught in the woods by a summer shower. But the fact of its development and existence is a clear indication of certain difficulties. The overhanging eaves are plain evidence that action of weathering is here more rapid than are the effects of erosion due to the plunge of the water. Instead of the cap rock being undermined at the base of the falls by the swirling of water in the pool and the resulting grinding action, as at Niagara, the retreat of the crest line upstream here is due primarily and almost exclusively to the crumbling of the weak underlying rock through subaerial processes. The thin falls make much spray. The rocks at the side and behind the water curtain are commonly damp to wetness. That dampness would make the place generally rather unattractive, not to say unhealthful, as a home site. It also serves to make the weak rock dissolve and decay. Then, in winter, by continuous addition and freezing, the wet from the spray builds up great ice masses all around the falls—not exactly ideal conditions at the door of one's home. The weight of this ice pulls rock fragments out and down.

Thus are developed the big overhanging eaves. The semicircular swing of the rock canopy extends so far on either side of the falls that the big amphitheater pit results. The amphitheater is surprisingly symmetrical. Probably changes in wind direction bring about an almost uniform distribution of the spray toward each side. This effect is commonly helped by the sun on bright days. In the morning the sun's rays fall on the rocks of one side, in the afternoon on the rocks of the other side of the amphitheater. As the rock becomes hot it causes the air in contact with it to expand, and a convection current is set up. A local wind, sometimes quite strong, develops. The air, and spray with it, moves from the cool area at the base of the falls toward and up the heated wall. In the afternoon the effect is directed toward the other side. Thus the rock walls below the falls are alternately heated and cooled, made wet and permitted to dry. Such rapid and numerous changes in conditions are particularly conducive to the crumbling of rock. It is obvious that the crumbling can not proceed indefinitely far back behind the falls.

At some distance back (how far will depend on the nature of the cap rock: how strong it is of itself; how much broken by joint cracks it is) the eaves, deprived of adequate support, will crash

TINKERS FALLS, LABRADOR HOLLOW, NEW YORK
HAS BIG OVERHANGING EAVES. THERE IS A WIDE, DEEP, STEEP-WALLED AMPHITHEATER IMMEDIATELY BELOW THE FALLS.

FALLS NEAR SPAFFORD LANDING, SKANEATELES LAKE, NEW YORK

HERE SEVERAL STRONG LAYERS ACT AS CAP ROCK FORMATIONS. SLOW RETREAT OF THE CREST PERMITS WEATHERING PROCESSES TO OPEN THE GORGE BELOW THE FALLS TO V-FORM AS RAPIDLY AS THE RECESSION OF THE CATARACT TAKES PLACE. THE OVERHANG IS SLIGHT AND THERE IS NO PLUNGE POOL.

down and the site of the falls will be established at a new point upstream.

It is easy to imagine these consequences and to contemplate a number of such crashes in succession causing the site of the falls to retreat rapidly upstream. Indeed, as natural processes go, the crumbling undermining here in progress is rapid. But in actuality, as measured by years, it is a slow business. The primitive home underneath the eaves might not be disturbed by a crash for several generations. Proof of such stability is to be derived from the fact that the slow erosion and transportation of the stream below the falls and the crumbling which accompanies these processes have been competent to dispose, quite completely, of the waste of earlier crashes and to open out the valley to a broad V form with much more gently sloping sides than those close up to the amphitheater.

Here we may make another interesting deduction. Although it is easy to see that the opening of the valley took much time, still a large number of the infrequent crashes must have occurred in order that the cut and amphitheater we are looking upon might be developed. Then the thought comes: this stream must have been flowing in the same volume, these processes must have been acting in the same way and at the same rate for ages and ages. We have perhaps been taught that the life-span of man is but a fleeting instant in the measure of all time, but we are confounded, despite this learning about human inconsequence, by such indubitable evidence of hoary age and perfection of stability manifested in a woodland brook and its waterfalls!

At another waterfall, quite small, unnamed, situated in a ravine which is cut into the eastern slope of Skaneateles Lake in New York, this story of variety in waterfall form and recession and of time, ages long, is given another turn. There the volume of water is, if anything, less than at the site we have been considering. Further, the strong cap rock is split up into several layers, with weaker beds of rock between them. Also, the weak rock downstream is not so very weak. So all in all the conditions for the production of a waterfall are reduced quite to their lowest dimensions. The division of the cap rock into several members makes the development of eaves difficult. The strength of the weak formations downstream altogether stops plunge-pool undermining. Accordingly we see no overhanging rock, no amphitheater. The falls appears simply as a straight line wall across the ravine. Here, in other words, weathering, a general term applied collectively to the various processes that cause rock to crumble, almost keeps pace with waterfall recession. The ravine is widened out to a V as fast as the brink of the falls moves back.

It becomes quite clear, therefore, using only these three examples as illustrations, that in the type of waterfall described, the type which is most common, great differences in form result according as the recession of the crest line takes place rapidly or slowly. The rate of recession in turn is noted to depend on the variable factors of volume, relative thickness and massiveness of the rock formations, relative durability of the cap rock and the underlying weaker beds. With so many variables each possible in so many degrees it is also quite obvious that the aspect, the scenic attractiveness of each waterfall site will be different. "See one and you see all" is a rule that distinctly does not apply to waterfalls. Yet the elements that bring about the differences in waterfall form are easily appreciated and understood. The waterfall enthusiast may apply them to each occurrence when he sees it for the first time. He will gain an intellectual satisfaction from the appraisal he makes and can thus happily supplement the esthetic thrill which even the callous tourist experiences at the sight of falling water.

THE RÔLE OF RELIGION IN A SECULAR AGE

By Dr. HARRY ELMER BARNES

I

THE struggle between science and religion to-day is but one phase of our general cultural complex in which we have, on the one hand, a very advanced scientific and mechanical civilization, while our ideas and institutions, on the other hand, retain the taint of primitivity and superstition.

The scientist is bound to come into contact and conflict with orthodox religion. In the first place, it is continually hampering his activities in different ways and by various methods. Even to-day he has to devote a part of his attention to protecting himself against anti-evolution laws and blasphemy laws. Then, if the scientist is an educator and has any self-respect, he desires to have his views of the nature of the cosmos, the universe, man and society dominate in the minds of men. The orthodox conceptions of the universe and man clash at every point with the scientific. The conventional religious view of the universe is one in which the earth is regarded as the largest and most important entity in the cosmos and the sole center of divine interest. Man is portrayed as primarily a theological exhibit who should be chiefly concerned with saving his immortal soul and securing an eternal life in the world beyond. Society is looked upon as the environmental equipment essential to test out man's fitness for salvation. Its codes and institutions are believed to have been divinely revealed and to be above legitimate criticism by man. The good life is not that which will make man most happy here on earth but that form of conduct which will make eternal salvation absolutely certain.

The scientific and esthetic conception is the direct opposite of all this. In the first place, we should make reference to the contributions of the evolutionary view-point. Here the first striking implication to be noted is the complete revolution of our time perspective which the evolutionary conception has made necessary. In the place of a very brief period of some six thousand years for the age of the earth and all living matter, we must reckon with a time conception which defies both the human imagination and our conventional standards of measurement. Hundreds of millions of years must be assigned to the earth in a minimum estimate, whereas the sun had passed its maximum radiance before the earth was separated from it in whirling particles. When one turns to the probable amount of time involved in the evolution of the cosmos, the conceptions and standards which prevail in measuring time for earthly purposes seem quite trivial and inadequate. Indeed, we may have to admit that, in the new cosmic time perspective, the very notion of time as we understand it may be nothing more than a convenient human illusion. Einstein and others have, indeed, suggested that time and space are but incidental manifestations of energy. The age of man in this new time perspective, instead of being coexistent with the duration of the earth and all the heavenly bodies, must be regarded as but the briefest trifle in earth history, to say nothing of its utter insignificance in terms of cosmic history.

Along with the revolutionized time perspective has come the dynamic notion of change as the vital and universal

principle of cosmic development. In the place of the older static notion of a perfect creation a few thousand years back, with but slight subsequent alteration of the nature of the heavenly bodies, the earth and its organic life, we have to recognize that change appears to be the most vital law of cosmic development and to realize that there is no such thing as a fixed and changeless condition to be observed in the universe. Everything is in a state of alteration, some of this being in the way of development and progress while other changes definitely manifest disintegration and devolution. We have, then, the conception of a dynamic and ever-changing universe in the place of the static outlook of a half-century ago.

A third vital implication of evolution is the fact that man has been demonstrated to be, not a theological exhibit a little lower than the angels or higher than the earthworm, but a highly organized biochemical entity, at the present time the temporarily dominant type in the animal kingdom inhabiting this planet. There seems to be nothing about human life or behavior which is in any sense unique and not susceptible of explanation according to naturalistic laws and principles.

The implications of modern astrophysics are absolutely destructive of the orthodox version of the Christian epic, as well as of orthodox Judaism or any other type of geocentrically circumscribed religion. The old view of God as a venerable and somewhat gigantic being, resembling man in every detail, frequently taking up his abode upon this earth and being at times accessible to call from his more faithful supporters; the notion of the earth as the chief product of the creative endeavor of God and the supreme object of his divine solicitude; and the view that Christ could have been in any literal sense "the only begotten son of God" offered up as a vicarious sacrifice for the sins of a small group of rather backward peoples dwelling at the extreme eastern end of the Mediterranean Sea—all such conceptions become easily and immediately recognizable as primitive anthropomorphic and geocentric misapprehensions.

Yet, while the earth is reduced in cosmic importance, its significance for man becomes greatly enhanced. We stand or fall entirely with our planet. We are alone in the universe of universes and all that counts for us is what takes place here on earth. Modern astrophysics, then, provides the framework for a truly mundane and secular outlook with respect to human life. We may survey the heavens and thereby cultivate terrestrial humility and cosmic reverence, but in our life aspirations and achievements we are thrown back solely upon our earthly habitat. Man can no longer be regarded as "the lord of all creation," but shrinks to the position of the highly organized mammal which has just now succeeded earlier species as the definitely ascendent form of organic life now existing on our planet. But if man dwindles in cosmic importance, he has been elevated with respect to his own pretentions. From now on we must realize that human problems are the only valid problems which face man and that the increase of our happiness is the only vital issue which confronts us. Society can not continue to be looked upon as the testing-grounds for the scheme of salvation but must be viewed as the means whereby man may, through cooperative endeavor, work out institutions and cultural traits designed to make his mundane existence ever more efficient, decent, happy and beautiful. The criterion of the good life is its relative contribution to the realization of such a mundane ideal. In the new outlook there would seem to be no good but human desires and their satisfaction, though we should recognize that the satisfaction of

desires may well express themselves in ever higher forms of manifestation and must be guided ever more perfectly by science and esthetics.

Now, in so far as the scientist has any pride, self-esteem and passion for enlightenment he must naturally desire to have his view of the universe and man prevail over the ancient religious interpretation which contrasts so directly and markedly with the scientific version. He may further legitimately demand that if we are to retain any conception of God, then that interpretation must be made compatible with at least the rudiments of the scientific knowledge concerning the universe and man.

An even stronger motive for a scientific criticism of orthodox religion may arise from the apprehension of the scientist that human misery and suffering are being increased and perpetuated by orthodox religion and from the belief of the scientist that he can reduce this suffering and increase human well-being. The scientist looks upon the great volume of fears and superstitions which obviously have not the slightest scientific validity, but, nevertheless, continue to influence countless millions. He notés the expense connected with the great organizations devoted to exploiting these superstitions and imaginary fears and reflects upon what might be done with such resources of money and potential intelligence in advancing the secular welfare of mankind. He considers the unhealthy and unhappy mental states which afflict millions in America to-day because of false theories of life inculcated in earlier ages when man was solely concerned with salvation and when he had no command of the scientific knowledge essential to the understanding of what constitutes a healthy and happy life here on earth. He surveys the suffering due to the widespread contraction of mental and nervous diseases which are a product of this same unscientific conception of desirable human behavior. He observes the wide prevalence of serious physical diseases that are to-day extant solely because of that prudery born of religion which prevents us from undertaking adequate education in regard to venereal prophylaxis. He contemplates the unspeakable suffering and the many deaths resulting from our barbaric laws regarding abortion.

He discovers families in dire poverty, and the world approaching the saturation point in population growth which may well turn humanity back into barbarism, as a result of the necessity for a struggle for bare existence—all on account of an archaic religious prejudice against birth control and population limitation. The candid observer of modern conditions must further note our barbarous divorce laws which degrade the institution of marriage and, in hundreds of thousands of cases, rob the family of the essential elements of freedom, sentiment and independence. They make it necessary to deal with the family as a theological entity—something which God has joined together—rather than as a secular institution designed to further social well-being. Likewise, he can not escape taking cognizance of a fanatical Prohibition scheme, parading under the guise of a "noble experiment," but actually debauching American morals and political loyalty, stimulating crime and corruption and paralyzing our system of criminal justice, with results as fatal to real temperance as to civilized modes of utilizing alcohol to promote human happiness. He observes many unscrupulous employers exploiting supernatural religion as a socio-economic anesthetic, thus enabling them to escape their decent obligation of adequate wages and satisfactory working-hours. By aiding the priesthood in their effort to perpetuate superstition and other-worldliness, they are reasonably successful in inducing the laborers to accept their

harsh and miserable life here on earth in the hope of better things in heaven. If he possesses, in addition to scientific knowledge and acumen, some degree of esthetic appreciation, the scientist must also deplore the ugliness, brutality and wastes which are inevitable by-products of the superstitions, prejudices and solemnity of orthodox, supernatural religion and its puritanical tendencies.

Once one observes these matters in a thorough fashion he is not likely to continue to believe that the scientists can persist in ignoring religion. If he is thoroughly conversant with contemporary conditions and issues the scientist will also contend that supernatural religion must be further criticized on the ground that it absorbs the intellectual efforts of many able men whose talents we need for the all-important task of coping with the increasingly complex problems of our material culture and our social institutions.

The above facts also constitute an effective rejoinder to the modernists who hold that we have passed through a revolution in religious thought and contend that the case against Fundamentalism is but an attack upon a bogy or a man of straw. In the first place, the theological revolution has affected only a few of American religious communicants —the majority still remaining loyal to the old concepts and dogmas. More significant, however, is the fact that modernist theologians, for the most part, support the Fundamentalist sociology, and, after all, the most important issue is that of the social effects of religion.

II

In entering upon the subject of the conflict of science with religion it is desirable for clarification to understand what type of religion is being discussed. We must be frank enough to admit that there is an eternal conflict between any true science and the type of religion represented by men like Cardinal Hayes, John Roach Straton, the late Mr. Bryan, Dr. Howard A. Kelley and the like. Between secular science and eschatological supernaturalism there can be no common ground, and neither group of adherents need be expected to give quarter to the other. One trusts in observation and is interested in secular or mundane happiness; the other rests on faith and is concerned with spiritual salvation in the world to come. The fact that Pasteur, Mendel and others have been both religious and scientists is of no avail in attempting to demonstrate that orthodoxy does not conflict with science. Mendel's researches were buried and had no significance until they were rescued by a non-Catholic evolutionary biologist. There was nothing in Pasteur's studies of putrefaction and pathology that raised any question of the conflict between science and supernaturalism. Let the question of birth-control be raised and Cardinal Hayes does not turn to his Mendel for his pronouncements but thunders forth that "little children come trooping down from heaven." Let the Catholics or the Fundamentalists of Protestant persuasion point to a single devout scientist of importance whose researches have dealt with problems which might directly jeopardize the standing of orthodoxy.

The conflict of science with devout modernism as represented by men like Dr. Fosdick is much less than that with orthodoxy. In many ways there is entire harmony of outlook and purpose. The criticism which the scientist would level against modernists like Dr. Fosdick is that they appear to keep the nomenclature and phraseology of the older orthodoxy while accepting the findings of modern science. They still preach in the name of Yahweh and Jesus. Yet Dr. Fosdick has himself presented a withering, indeed, extinguishing critique of Yahweh, and his theological learning,

scientific knowledge, social experience and esthetic appreciation far surpass any pretensions or achievements of Jesus in these fields. Therefore, he can speak in his own name and on his own authority with far greater effect than he can preach in the name of Yahweh and Jesus.

The scientist would also deplore the retention of the term "spiritual" by the average modernist as implying something apart from the secular and incapable of scientific scrutiny and measurement. It would be far better to discard this anachronism and use the terms psychological and esthetic for what the modernist really means by spiritual. The scientist can not concede the existence of any mysterious spiritual entity apart from the forces and tendencies which he studies. The scientist, natural or social, would also insist upon the relinquishment of another ancient animistic conception, namely, the category of "sin." Sin connotes a supernatural conception, namely, the violation of the explicitly revealed will of God. To-day, when we recognize that there is no method of proving God's existence, to say nothing of his nature and will, it is obvious that we can not possess the prerequisites of sin. This archaic term should be abolished, and all forms of antisocial action should be isolated and differentiated on the basis of their mundane results. No act can be regarded as bad unless it reduces human happiness and the beauty of life. Acts which are thus harmful should be rechristened with contemporary secular terms like crime and immorality. The notion of sin and of the supernatural origin of morality only confuses, complicates and obstructs clear thought and constructive action in these fields.

Likewise, in regard to the reconstruction of social conditions, the scientist would object to the effort of men like Sherwood Eddy to justify their brave struggle for social justice on the ground that it conforms to the teachings of Jesus. We herewith reproduce the authoritative summary of Mr. Eddy's truly noble principles of Christian socialism, which embody a splendid conception of human altruism and social reform but is justified through an appeal to Jesus' way of life:

> Believing in Jesus' way of life and in his all-inclusive principle of love as the full sharing of life, I therefore determine to apply this principle in all the relationships of life:
>
> (1) To live simply and sacrificially, avoiding waste and luxury. To make the purpose of my life the making of men rather than the making of money. Not to grow rich in a poor world by laying up treasures for myself but to share all with my fellow men. To apply the golden rule in all my relationships.
>
> (2) To practice brotherhood toward all. To remember that every human being is a person of infinite worth, deserving the fullest opportunity for self-development. To participate in no secret order or fraternity if it tends to exclusiveness, prejudice or strife. To seek justice for every man without distinction of caste or color.
>
> (3) To make peace where there is strife; to seek to outlaw war, "the world's chief collective sin," as piracy and slavery have already been outlawed, substituting a positive program of international justice and good will.
>
> (4) To redeem the social order; to test its evils by the principle of love and fearlessly to challenge them as Jesus challenged the money-changers in the temple. To endeavor to replace them by the constructive building of the new social order, the Kingdom of God on earth. If a student, to apply this purpose immediately to the problems of our campus; to seek education as training for service rather than the mere enjoyment of privilege, the attainment of grades or the achievement of cheap "success"; to tolerate no dishonest practices in classroom, athletics or college elections; to maintain no relationships with my fellows, men or women, which violate absolute purity or debase the divine value of personality. Since I realize my inability to achieve this way of life unaided:
>
> (5) To seek a new discovery of God which will release within my life new springs of power such as men in the past have experienced when they rediscovered the religion of Jesus.
>
> In order to carry out this five-fold purpose, I will seek immediately to associate myself with others for the purpose of study and experi-

mentation in the realization of Jesus' way of life.

Now Mr. Eddy has traveled widely through the world, observing all kinds of labor conditions and social situations, and he has counseled long with the foremost socio-economic experts now alive. Therefore, his own views on modern social and economic conditions should command more respect than those of Jesus who lived a restrained and provincial existence in a very backward economy. In other words, we should like to hear more and more of what Dr. Fosdick and Dr. Eddy have to say on their own authority and less of their palpably hopeless effort to discover a consistent and relevant social philosophy on the part of Yahweh and Jesus and to apply this to conditions quite different from ancient Palestine in the time of either Jesus or Moses. Of course, if Drs. Eddy, Fosdick, *et al.*, retain the old nomenclature merely for its pragmatic value in working with those familiar with and attached to this terminology, then there is little to criticize in their conduct.

When we come to Unitarian humanism, as upheld by men like Drs. Dietrich, Slaten, Holmes, Reese, Robinson, Randall and the like, and liberal esthetic Episcopalianism, as represented by such men as Drs. Reiland, Humphries, Guthrie and others, the conflict between science and religion is relatively slight. Both groups accept the same scientific view of the cosmos, the universe, man and society, differing only in their respective interests and life endeavors. This advanced modernism is really more of a social philosophy and a branch of ethics and esthetics than anything resembling the old savage anthropomorphic and geocentric orthodoxy.

On one important point, however, even some of the exponents of so advanced a position as Unitarian humanism must modify their views if they are to be compatible with science. What we have in mind is the doctrine of the freedom of the will. In Dr. Curtis W. Reese's excellent summary of Unitarian Humanism ("Humanism," pp. 38–9) he says: "The moral life begins with freedom to choose or not to choose a line of action; and no moral significance can be attached to any action in the absence of this freedom." To be sure Dr. Reese tries to identify this moral freedom with the control of the emotions by an intellect well stored with knowledge. This, however, confuses two quite different issues and problems. Further, knowledge appropriated and interpreted by the intellect is as much involved in the deterministic process as our emotional impulses. The very fact that we are able to control our life on the basis of knowledge, as Dr. Reese insists, logically implies that we are not free from the determining effect of this information. What Dr. Reese actually means is that we should more and more thoroughly control our life on the basis of reliable information regarding the good life on earth which has been amassed by natural, psychological and social science. He should not contaminate and defile this noble aspiration by in any way identifying it with the archaic theory of free will, which has no more standing before modern psychological science than the Hebraic "firmament" has in the light of the astrophysics of Jeans, Einstein, Shapley, Eddington and Dingle.

It need scarcely be pointed out that there is no basis for essential conflict between science and the Christian socialism expounded by men like Norman Thomas, Bouck White, Upton Sinclair and others. These men derive the justification of their views from secular rather than supernatural considerations. The only issue is the degree to which their opinions and programs square with the best social and economic science. The question of the clash between supernaturalism and secularism does not emerge in this case.

It will doubtless be a splendid thing in this place to comment decisively and unequivocally upon one very prevalent but extremely disingenuous method of dealing with the critical attack upon orthodox religion, namely, to declare that it is all "old stuff," that it is generally accepted by all up-to-date theologians, that the attack is entirely unfair to the religious cause, and that there are really no more orthodox believers. The writer recognizes that the attack on orthodoxy goes back as far as the Egyptian emperor, Ikhnaton, about fifteen hundred years before Christ, if not before. He is not unaware of the attack upon orthodoxy by the Sophists and by Lucretius and the Epicureans. Further, he has made a special study of the assaults on orthodoxy by the Deists and other liberal theologians from 1650 to 1800. He is well aware of the heterodoxy of the Fathers of the Constitutional period in our own country. He is fully conscious, finally, that all he has stated in the recent controversy has been the common property of scientific students of religion for a generation.

All this is, however, quite a different thing from admitting that orthodoxy has no appreciable following in the country to-day and that to attack orthodoxy is to attack a bogy and a man of straw. The writer may offer the following in support of the thesis that this particular rejoinder to criticism is made in bad faith. During the last ten weeks the writer has probably received as extensive a number of representative letters on religion as any other person in the history of religious controversy in a similar period and he has been able to peruse a vast number of comments on the controversy in the press throughout the country. Now if his statements are to be condemned as "old stuff" and an irrelevant attack upon a non-extant body of belief, it is quite evident that those who would have the best reason for complaint on this ground would be the advanced religious thinkers of America—those who have passed farthest from orthodoxy. Yet, so far as the writer is aware, there has not come a single complaint upon this ground from the leaders of advanced religious thought in America. In letters or in the public prints the writer's stand has been commended as both timely and sound by such men as John H. Dietrich, Albert C. Dieffenbach, A. Wakefield Slaten, John Haynes Holmes, Alson H. Robinson, John Herman Randall, William Montgomery Brown, Archdeacon Humphries, Minot Simons, Henry Darlington, Charles Francis Potter and Rabbi Feinberg, to mention only a few representative names. On the other hand, those who have raised the "old stuff" dust have invariably been such wabbly modernists as William Adams Brown, H. E. Luccock, Henry N. Wieman, *et al.* Now we are not for a moment contending that the supporters of the writer's general position are right and flaunters of the "old stuff" slogan wrong. It is merely submitted that, if there were anything valid about the "old stuff" argument, the real leaders of the most advanced religious thought in America would be those who would be exploiting this position. The writer contends that the tendency to cry "old stuff" is an evasive method whereby conservative modernists hope to stem the tide of thoroughgoing criticism while offering to the public a gesture of pseudo-modernism.

III

We have just considered the matter of the conflict of science and religion from the standpoint of the different classes of religious leaders and the varying levels of religious beliefs. We may now examine the question briefly from the point of view of those scientists who have offered their services as liberal theologians and have declared that there is no conflict between science and religion.

Among the best known of these have been the eminent British biologist, J. Arthur Thomson, the brilliant American physicists, Robert A. Millikan and Michael I. Pupin, the prominent zoologist, Henry Fairfield Osborn, and the active Harvard geologist, Kirtley F. Mather. These men, and many others of their kind, have valiantly proclaimed that there is no conflict between science and religion. The most decisive and lyrical pronouncement is the following statement by Professor Pupin. It is the summary of an interview with him by Mr. A. E. Wiggam, the well-known popularizer of modern eugenic doctrine, and published in the latter's "Exploring Your Mind" (pp. 385–6). A more extended view of Professor Pupin's views may be discovered in his "The New Reformation," but the following summary by Mr. Wiggam will suffice to make clear the tenor of Professor Pupin's views:

> Science is making us better Christians.
>
> Science teaches us that the Universe is guided by an intelligent Divinity.
>
> Science is teaching men how to cooperate intelligently with God; it is teaching men what his laws are and how to obey them.
>
> Science is proving that the human soul is the greatest thing in the Universe, the supreme purpose of the Creator.
>
> Science is leading us closer and closer to God.
>
> Science has made us better homes and is teaching us how to make a better democracy and a better social life; it is thus preparing us for the greatest spiritual, artistic and intellectual life that men have ever known.
>
> Science does not contradict belief in the immortality of the human soul.
>
> Science is revealing God in greater and greater glory, and teaches us that in time we may possibly even see Him face to face. . . .
>
> President Nicholas Murray Butler, of Columbia University, is reported to have said recently that, while talking with Dr. Pupin, he felt that he was witnessing the curtain being lifted upon a new and brighter world. I believe he would make you feel the same way, and I should like to convey that feeling to you through his own words.

The reconcilers from the scientific camp support their case in many ways. A familiar method, used by both Cardinal Hayes and Dr. Osborn in their condemnation of the writer's paper before the New York Academy of Medicine and the History of Science Society last December, is to enumerate an impressive list of scientists who were devoutly religious. The Catholic register will always contain Albertus Magnus, Roger Bacon, Copernicus, Galileo, Pascal, Mendel and Pasteur, but those who exploit it never call attention to the rudimentary and inoffensive observations of Albertus, to the clerical persecution of Bacon and Galileo, to the ecclesiastical intimidation of Copernicus, to the notorious compartmentalized mind of Pascal, to the fact that Mendel did not dare to give publicity to his researches in genetics and that they were recovered and disseminated through the efforts of non-Catholic evolutionary biologists, and to the fact that Pasteur's researches in pathology in no way raised issues which conflict with orthodox theology. This appeal to the list of names of religious scientists is both infantile and ineffective unless one examines each scientist individually, to discover the nature of his scientific work and his competence to discuss religion. The fact that a man may be an eminent physicist does not, in itself, entitle him to speak with any more authority upon religious questions than would the possession of an enviable record as a skilful blacksmith or plumber. There are a number of classical examples of internationally famous physicists and chemists who, with great gusto and pride, continue to conduct Sunday-school classes in orthodox religious circles. A great scientist, who is religious in an orthodox sense, either offers one more example of the notorious capacity of the human mind to compartmentalize itself and entertain mutually exclusive conceptions and attitudes, or is an illustration of the one-sided nature of our present-day education, which allows a

man to participate in the physics of Einstein and yet share the religious outlook of his Methodist or Baptist grandmother.

Professor James Harvey Robinson, in *Harper's Magazine* for September, 1928, has offered a very ingenious and convincing explanation of the so-called compartmentalized mind, in so far as it relates to the religious question. He holds that our religious beliefs and attitudes remain essentially on an infantile level, while we carry further the development of our psychic life in the field of science, technology, art, literature, and the like. In other words, the pious physicist is a person whose scientific views are on an adult plane, while in the religious field he is intellectually a youth in short pants. We may here quote the most cogent section from Robinson's views:

> Bryan exhibited through his life no more knowledge of religious matters than he could have easily acquired at ten years of age. Sermons of the commoner sort contain only what both preacher and audience accepted before they were grown up. Religion does not tend to mature in most cases. It is what we learned at our mother's knee. In later life we are preoccupied with business and amusement, and there is no time to keep up with the course of religious investigation, even if we had the slightest disposition to do so. Billy Sunday talks as a big husky boy to other boys and girls. Even distinguished scientific men solemnly discuss the relation of religion to science, when, if they but stopped to think, they would find that they were assuming that they know all about religion, without having given it much thought since childhood; although they would readily admit that after a lifetime's work they knew very little about science.

Dr. Thomson seeks to harmonize science and religion by the well-worn device of holding that science is supreme in the realm of the intellect while religion reigns over the emotions. As Professor Max Otto has well pointed out, this is no solution of the problem at all, for emotions do not function *in vacuo*, but associate their expression with definite beliefs, most of which have thus far in human history been contrary to the well-established facts of science. Indeed, the great value of psychological and social science lies in its potential service to the achievement of a scientific control and direction of the emotions. Professor Millikan resolves the conflict between science and religion by redefining religion in such a manner as to divorce it entirely from orthodoxy and to make it the inspirational adjunct of ethical dynamics. It is to be the great psychological stimulant to social well-being. As long as it is kept in general terms there can be no serious fault found with this suggestion. The difficulty comes in the recognition that this does not alter the fact that there remains a conflict between science and the orthodox cults which Dr. Millikan rules out as true religions. Yet one must remember that for one religious person who accepts Professor Millikan's view of religion as "the great dynamo for injecting into human society the sense of altruism" there are a thousand who enthusiastically espouse the primitive doctrines set forth by Cardinal Hayes and John Roach Straton. Dr. Osborn endeavors to prove that no conflict exists between science and religion by essentially the same means as does Professor Millikan. He strings along the threadbare list of devout scientists and then arbitrarily defines science and religion in such a fashion as to make religion accept the facts of science as a point of departure, something which orthodox religion is singularly loath to do in actual practice. Professor Mather employs another time-honored expedient, namely, that of denominating all the facts and processes of nature as essentially miraculous. He thus gives evidence of a sad lack of information regarding technical theological terms, for a miracle is by definition something which defies not only all existing but all probable future scientific explanation. Professor Mather errs by

confusing the term miraculous with the term impressive. We agree with Professor Mather that much, if not all, of nature is remarkably impressive, as one will perceive by recalling such a masterpiece as Huxley's lecture "On a Piece of Chalk." Yet that is quite a different matter from holding nature to be inexplicable. Moreover, miracles do not necessarily lead us to God and religion. Where science is baffled religion certainly can not offer reliable or assured guidance. With Professor Pupin's pronouncement we need not concern ourselves. It is nothing more than the explosion of a "will-to-believe" which could have been uttered by either Cardinal Hayes or Dr. Straton. It is purely a product of Professor Pupin's subjectivity and entirely incapable of scientific demonstration. It lets us know quite definitely how Professor Pupin personally feels on the subject of science and religion, but it takes us nowhere at all in getting at the fundamental issues involved. Wishful thinking does not take on the attributes of profound science or critical philosophy merely because it issues from a great laboratory physicist. It is still wishful thinking and nothing more.

In his important book, "The Nature of the Physical World," the eminent British physicist and astronomer, A. S. Eddington, admits that the new doctrines of electrodynamics do not lead us directly to a formulation of a specific and demonstrable conception of the new cosmic God, but, as a Quaker, he attempts to show how they enable us to formulate a defense of the old theological conception of free will or the freedom of human choice. As Bertrand Russell has well insisted, Professor Eddington is compelled to make certain gratuitous assumptions in regard to electrodynamics in applying its principles to psychology, but even more important is the fact that the question of the freedom of human choice is not an issue to be solved by an appeal to physics. It must be dealt with in relation to the processes of conditioned-response which are studied by psychology and sociology. If physics does not lead us directly to God, it is as patently evident that it does not lead us to the solution of the fundamental problems of human behavior. These are issues of an order as remote from physics as are the theological problems connected with God. If there can be no "quantum theory of God," as Professor Eddington admits, there can be no quantum theory of human behavior.

Finally, we may put at rest a venerable antique in the realm of apologetics, namely, the assertion, given wide currency by Andrew D. White, to the effect that the conflict is not between science and religion but between science and theology. This differentiation between religion and theology is one which has been abandoned by all up-to-date students of religion. Religion has three major manifestations: (1) the emotional thrill; (2) the behavior responses or ritualistic exercises engendered by this thrill, and (3) the conceptual interpretations and explanations of the religious thrill and the activities associated therewith. This third phase of religion is what has been known as theology. Therefore, theology can not be separated from religion. A theology is as tenable as the religious emotions and activities upon which it is based, and of which it is the rationalized explanation. If the religious thrill arises from unscientific assumptions and interpretations, then there is as much conflict between science and the religious emotions as between science and the theological formulations in that particular religious complex. If the activities and moral code growing out of the emotional basis of a religion are scientifically unsound, then there is as definite a clash between science and the religious rites and morals as between

science and the conceptual formulations. Inasmuch as theology represents the intellectual manifestations of religion, it is obvious that the most sharp and direct conflict comes between science and theology, but this is quite another thing from holding that there is no conflict between science and religion—that the issue is solely one between science and theology.

IV

The writer believes that, if humanity and civilization are to be preserved, we must, perhaps, have collaboration between science and an advanced secular religion. He readily concedes that neither Bertrand Russell, John B. Watson, Clarence Darrow nor George Dorsey has any need for God or religion in order to behave in a seemly or intelligent fashion, but, with half of the American population falling below the intellectual level of the dull normal type, we certainly shall require some form of social control beyond the appeal to pure intelligence. Further, there are many capable persons whose affinities are more with esthetic considerations than with matters of cold intelligence. For these types of human beings a social institution which could exploit human emotions and place them behind just and decent causes will prove indispensable. Such a secular religion would, of course, obtain its factual guidance from science, natural and social, but would aid science in the social application and execution of such facts.

In taking up the relation of science and God, it is evident to any informed person that the very elements of modern science, together with even the rudiments of an understanding of biblical scholarship, completely undermine and dispose of the biblical God, Yahweh. This necessitates a complete reconstruction of our views of Jesus, who owed his uniqueness to the claim that he was the only begotten son of Yahweh. From now on, Jesus must be studied as purely a secular and human religious teacher, concerning whose existence there is but slight information and regarding whose doctrines we have but fragmentary and often conflicting evidence. No contemporaneously minded person could pretend that the views of Jesus on any subject related to modern life can carry any such authority as those of Dr. Fosdick, Dr. Holmes, Dr. Reiland, Bishop McConnell or Rabbi Wise. This is a fact which the modernists have usually been loath to concede. They will admit the passing of Yahweh but cling to a view of Jesus that rests almost wholly on his alleged relationship to Yahweh.

As to whether a new conception of God may be constructed, the writer frankly admits that he does not believe it possible to arrive at any precise conception of the new cosmic God, if there be one. The whole search for a God is based on primitive human aspirations; the very facts of the physical universe, in terms of which the new cosmic God must be constructed, evade and baffle the limited human mind; we can only formulate notions of God in terms of our own experiences and categories, which are obviously wholly unsuited as a framework for the picture of the cosmic Almighty; and the basic hypothesis involved, namely, that all things must have a maker and a purpose, may well be a geocentric human illusion. In searching for a "first cause," we must remember that both "first" and "cause" are human inventions and categories which may have no general cosmic validity whatever. Therefore, it would seem that the quest for God in the new perspective is likely to prove futile. Yet it is a noble quest, certainly far more lofty than the search for an additional million dollars or a higher political office, and we can cast no aspersion upon those who carry on the search. Manifestly, in so far as the quest for a new

God helps on the abandonment of Yahweh it will be a great gain for humanity and civilization.

The question of the adequacy and sanctity of the ten commandments and the beatitudes is inseparably related to the problem of Yahweh, Jesus and the Bible which we have just discussed. They have no sanctity other than that which may reside in their validity. Some of the ten commandments, like the taboo on swearing and on Sunday labor, are obviously primitive superstitions. Other sound ones, like the commandment against killing, are incomplete and need elaboration in an age which is so highly versatile in its talent for murdering. Moreover, the ten commandments were devised for a very simple economy. If ten commandments were essential for primitive Palestine, then we should need five hundred for adequate guidance in twentieth century New York City. In short, the ten commandments are a primitive collection of social usages, having no more sacredness about them than the sound passages in the Code of Hammurabi. Many of the commandments should be obeyed to-day, but not because they occur in the Bible. They should be followed, if at all, only because they square with the needs of life in our era. The same may be said regarding the beatitudes and other sayings ascribed to Jesus.

The new religion, if sound and practicable, must rest on a thoroughly secular basis, secure its facts from science and conceive its ideals in terms of sociology and esthetics. It must become accessory to the new queen of the sciences, mental hygiene.

V

It follows as a matter of course that such epoch-making changes as we have described above, with relation to the status of orthodox religion in the light of modern science and critical thought, make necessary a searching reexamination of the place and function of the church in modern society. In the first place, the new view of matters makes it very evident that the clergyman can no longer pretend to be a competent expert in the way of discovering the nature, will and operations of the new cosmic God. If undertaken and solved at all, this is a problem for the cooperative endeavors of the natural scientist and the cosmic philosopher of the Dewey vintage. At best the theologian can only be a competent second- or third-hand interpreter of the facts and implications gathered about the cosmos and its laws by specialists in science and philosophy. In the old days, when it was thought that God might be reached and understood through prayer, sacrifice or revelation, the clergyman or theologian was indeed "the man of God" who could make clear the will of the Deity to believers. But now when God must be sought, if at all, by means of the test-tube, the compound microscope, the interferometer, the radium tube and Einstein's equations, the conventional clergyman is rather hopelessly out of place in the premises. Therefore, it is apparent that the intelligent and educated theologians must surrender their age-long pretension to special, if not unique, competence in clearing up the problem of the nature of God and His laws. They can at best be little more than ringside spectators of the observatory and the laboratory, doing their best in the way of an amateurish appreciation of what is going on therein.

Next to the revelation of the nature of God and his ways, the most time-honored function of the so-called "man of God" has been to unravel God's will with respect to human conduct and to inculcate the absolute and inflexible principles which should control personal morality, in order that the soul of the individual might be assured of an ultimate refuge in the New Jerusalem. This was a perfectly rational and logical function for

religion when it was commonly assumed to be axiomatic: (1) that the purpose of moral conduct was to insure the salvation of the soul, and (2) that the supreme and complete guide to moral living was to be discovered in Holy Scriptures. Neither of these fundamental postulates can be sustained today. There seems to be no ground whatever for the orthodox views of a bodily or spiritual immortality and the imminence of a literal heaven and hell. Hence, the basic objective of right living can no longer be regarded as the insurance of spiritual salvation. On the contrary, the fundamental purpose of the good life is to secure the maximum amount of happiness for the greatest possible number here upon this earth. Therefore, it is readily apparent that accurate guidance to the good life can not be sought in ancient Scriptures or provided by specialists in Holy Writ. The moral code of the future must be supplied by the specialists in mundane happiness, namely: biologists, physiologists, psychiatrists, educators, social scientists and students and practitioners of esthetics.

Some who frankly admit the incompetence of the clergyman and the theologian in the way of providing original and conclusive guidance to moral conduct contend, nevertheless, that the church can exercise a very valuable service in interpreting and popularizing the findings of the specialists in human happiness. This may be true, to a certain extent, but many qualifications would have to be added. Many phases of guidance to complete human happiness would necessarily be a highly technical and individual matter, to be handled by medical and other experts in relation to individual cases and problems, and would scarcely be adapted to comprehensive general interpretation or exhortation.

Some writers, among them the scientific reconciler, Professor Mather, contend that religion is essential to ethics in that it enables us to be "something more than ourselves," while scientific ethics admittedly can only enable us to make the most of ourselves. No answer is needed for this contention beyond asking Professor Mather to describe *just what is implied* in man's being more than man and just how a scientifically minded person could conceive of such an achievement. We further submit that it is quite enough of a problem to enable man to make the most of himself, and we further suggest that thus far religion has mainly succeeded in making us much less than ourselves.

A much better case can be made for the service which may be rendered by religion in inculcating an interest in and respect for such large and scarcely debatable moral conceptions as justice, honesty, pacifism, cooperation, kindliness, beauty, etc. Professor Kirsopp Lake has well stated the case for the desirability of having religion relinquish interest in sumptuary moral control and assume responsibility for the advancement of more profound and general moral principles:

> One man may find much comfort in tobacco, while another may injure himself by smoking; one may err by playing too much, and another by never playing at all. I doubt whether the men of to-morrow will try to interfere with each other on these points, knowing that the thing which matters is ability to do good work, and that one man can do his best work in one way, another otherwise. Many of the things Puritans condemn are strictly indifferent. The religion of to-morrow will recognize this, it will give good advice to individuals, but not lay down general rules for universal observance.
>
> On the other hand, it may have a sterner standard in business, industry and finance. It may insist more loudly that honesty applies to the spirit of business, not merely to its letter. It may even demand that men must be as trustworthy in advertisements, business announcements and journalistic reporting as they are in private affairs. For these are the questions of morals which are the issues of life and death for the future. They are not covered by the teaching of Jesus or of historic Christianity, for neither ever discussed problems which did not exist in their time. Some of the principles

which have been laid down by them will play a part in the solution of these problems but probably others will also be needed, certainly the actual solutions will contain new elements, and the religion of to-morrow will have to look for them.

One can scarcely quarrel with Professor Lake on theoretical and logical grounds, but there is an important practical consideration, namely, that the modern social and economic order is based to no inconsiderable degree upon intrigue, shrewd business enterprise, relentless competition, unreasoning patriotism and class selfishness. It can scarcely be expected that the custodians of the modern order, who provide the chief pecuniary support for our religious institutions and organizations, will contribute with enthusiasm to a movement designed to cut at the root of many of the principles and practices which they hold most sacred and indispensable. Before the church could achieve much in this field it would be necessary to organize and carry on a very definite propaganda of education in the principles of social ethics broadly conceived. Thus far, however, few clergymen so orientated and motivated have been able to maintain their position long enough to make much headway in this educating process. As far as the writer is aware, there has been no marked or organized effort to draft the services of Sherwood Eddy, Norman Thomas, Kirby Page, Bouck White, Ralph Harlow, Harry Ward, David D. Vaughan and others of their kind and induct them into the pastorate of great metropolitan churches.

The supervision of the church over recreation, which has in the past been exercised chiefly in the way of an arbitrary decision as to what are immoral and what are moral forms of recreation and in closely scrutinizing and controlling the activities of individuals in these fields, must now be sharply challenged. The orthodox religious criteria as to moral and immoral forms of recreation were not based upon physiological, psychological or social grounds, but upon theological considerations which have little or no validity in the light of modern knowledge. The church, having no competence in the matter of determining the nature of moral and immoral conduct in the light of modern secularism, obviously can not apply its decisions in this field to the realm of recreation. Recreation, like morality, with which it has been so closely associated in the past, is a field for the secular expert and must be handed over to biologists, medical experts, psychologists and social scientists. The church at most could scarcely go further than to proclaim the general desirability of healthy and adequate exercise and the exhibition of a proper spirit of good sportsmanship.

Another function of the church in the past which has received much support relates to its esthetic services. It is held that the ritual, pageantry and liturgy of the church provide a relatively economical and highly valuable esthetic service to humanity. This is, of course, an argument which can be far better justified from the Catholic standpoint than from the Protestant, the Protestant churches having given up most of the splendor of the Catholic service. This argument boils down to the allegation that the church is in a position to "put on a better show" for the populace and at a lower cost than any other comparable secular organization. While there is much to be said in support of this view in regard to the services of the church in earlier periods, it would seem that this function may be, and indeed is, now achieved more adequately and cheaply by various secular enterprises, such as the grand opera, the theater, the movies and various types of public pageantry. Further, many contend that the attitude of fear and awe generated by religious ritual and pageantry produces a fundamentally unhealthy state of mind which, to a large degree, offsets

the esthetic services contributed thereby.

Therefore, it would seem pretty definitely established that the conventional functions of the church have well-nigh completely evaporated in the light of contemporary knowledge and intellectual attitudes. It must be conceded that the theologian is no longer needed to chart out and control the supernatural world and supernatural powers, inasmuch as the existence of such entities can scarcely be established. It is equally apparent that the theologian can not by himself locate, describe or interpret the new cosmic God believed by some to be implied in the discoveries of modern science. Neither can the theologian supply detailed moral guidance in the way of indicating how man must live in order to achieve the maximum degree of happiness here on earth. Nor can the church support its ancient pretensions to guiding and controlling recreation or in supplying popular pageantry. This raises the important question as to what the church can legitimately engage upon in harmony with the tenets of an open-minded and contemporaneous secular attitude.

It would seem that the most reasonable field for the functioning of religion in contemporary society is in the way of providing for the mass organization of the group sentiment of mankind in support of the larger principles of kindliness, sympathy, right, justice, honesty and decency. Just what constitute the essentials of right and justice would have to be determined by the appropriate scientific and esthetic experts, but these experts have little potency in the way of arousing ardent popular support for their findings. Religion has thus far been the most powerful agency in arousing and directing the collective will of mankind. Therefore, we may probably contend with safety that the function of a liberalized religion, divested of its archaic supernaturalism, would be to serve as the public propaganda adjunct of social science and esthetics. The social sciences and esthetics would supply specific guidance as to what ought to be done, while religion would produce the motive power essential to the translation of abstract theory into practical action. There would, however, be ever present the problem of restraining this educational propaganda and keeping it in thorough conformity with the recommendations of science and art. The function of the church, then, would be to organize the mass mind and mass activities in such a fashion as to benefit secular society and not to please God, at least not as God has been understood and expounded in the orthodox religions of the past.

The writer is inclined to support this conception of the future and permanent function of the church, though there are some observers of high standing who declare that the secular lecture platform is more suitable and adequate, and that the public forum and the public schools must ultimately supplant the ecclesiastical edifice as the center of intelligent propaganda and the development of collective sentiment for social improvement.

It would appear to the writer that the problem is not so much one of the nobility or the validity of this function of religion or one of its value to society, but rather the question of whether or not the church can successfully carry out such a type of social service. The issue is primarily the one of whether an organization, hitherto almost exclusively devoted to the understanding, control and exploitation of the supernatural world, can be completely transformed into an organization for the purpose of increasing the secular happiness of mankind here on earth. Such a transformation would imply a complete revolution in the premises and activities of religion, and we have little or no evidence from the past to give us any definite as-

surance that so profound a transition is practicable or attainable. The issue is fundamentally whether organized religion can be held together and can operate without a sense of mystery and a fear of the unknown. The thrill from the mysterious has been the core of all past religion, and we have nothing to give any final assurance that religion can persist without this dominating element of mystery and fear. Certain writers contend that there will always remain a certain fringe of mystery, particularly in the way of unsolved scientific problems, as well as the general mystery inherent in the riddle of the universe. But, as Professor Shotwell has well indicated in his "Religious Revolution of Today," the mysteries of modern science are quite different in their premises, manifestations and psychic effects from the conventional religious mystery based upon an emotional reaction to a hypothetical supernatural world. The reaction to the mysteries of science does not promote that group-forming tendency which Ward, Hankins and others have shown to be so characteristic an effect and accompaniment of supernatural religion. Abstruse scientific perplexities and the riddle of the universe may promote advanced forms of cerebral effort but they are not likely to evoke a sentimental thrill or to generate a crusading passion in human assemblages. Indeed, some leading social scientists contend that the divergence between the old supernaturalism and the new secular program is so great that no real common ground can be found. Hence, they argue that we should not contaminate and confuse the new secular type of ethical enterprise by denominating it religion. This is certainly a consideration which is entitled to receive serious thought.

It is held by many that the majority of mankind will always remain essentially superstitious and victims of supernaturalism. While not optimistic with respect to the possibilities of rapid intellectual emancipation on the part of the majority of men, nevertheless, the writer questions seriously whether or not we may assume the indefinite prolongation of the domination of man by superstition and gross supernaturalism. Even the most benighted southern Baptist of to-day is almost secular in his daily life and attitudes as compared to the medieval peasant or the unconverted Indians of America though he may formally adhere to a primitive cult.

EVOLUTION AND RELIGION

By AUSTIN H. CLARK

U. S. NATIONAL MUSEUM

No question is of greater importance at the present day than that of the relation of science to religion. We in the United States are now definitely embarked on what in the years to come will be regarded as a type of culture new in the history of man, a culture chiefly characterized by the increasingly broad application of the correlated facts of science to our daily lives.

Many regard this type of culture now rapidly developing as wholly materialistic in its nature and as a growing menace to the non-material side of human life. They argue that by affording in rapidly increasing measure opportunities for recreation and for diversion it is correspondingly inimical to the more serious cultural and spiritual phases of human understanding.

But is this true? We are prone to judge conditions by the most obvious phenomena connected with them, by those phenomena which intrude themselves on our attention, either in our personal every-day experience or as supplied to us through magazines and newspapers. We are all too likely to forget that perhaps these are only superficial, transient and to us unwelcome attributes of a social readjustment.

History shows us that after all human nature has through the ages remained fundamentally unchanged. Outward appearances have undergone marked variations from one epoch to another, but as a rule these have affected only a small proportion of the people, or else have been wholly superficial.

Since the basis of the new conditions is the ever-increasing application of the facts of science to our material welfare, it is fitting that we should survey the present situation and from this survey ascertain so far as possible both what the present situation is and what the future has to offer.

One hears it commonly remarked that a firm belief in science eventually will supplant religion, or at least so modify it that it will be a wholly different thing from the religion that our fathers knew. One also hears it said that science and an increase in scientific knowledge eventually will be blocked by the growing opposition of religion.

Neither hypothesis is tenable. There can be no conflict between science and religion. For truth is truth quite regardless of the manner in which it may have been attained, whether through the paths of science or through religious teachings.

Through religion all of the very numerous factors, material and non-material, which in any way bear upon human existence, both individual and social, are coordinated. Religion contemplates order in all things, whether touching human affairs or not. But when subjected to analysis, everything is found to have a bearing more or less direct upon human activities and human welfare.

Through scientific investigation we are striving to discover and to correlate the facts which will enable us to understand the ultimate order upon which the universe, in the broadest application of that term, is based, and in addition we are endeavoring to find the means of applying such elements of this order as we are able to determine to human activities with a view to the betterment of human welfare.

Science, therefore, is engaged in building up a structure which should serve to strengthen the foundations of religion, not to weaken them.

Approaching the same end by different paths, the one material and the other

spiritual, there would seem to be no reason why science and religion should not go hand in hand, and, working together, hasten the mutual progress toward the common end.

But, like all things human, science on occasion becomes directed into paths that seem to run counter to religion. Perhaps the best example of such a manifestation at the present time is afforded by the concept which is known as evolution.

What is evolution? Evolution is commonly defined as a doctrine which assumes the gradual development step by step of all the widely varying forms of life from an original form of simple structure. While technically correct, this definition is somewhat misleading. It is obvious to every student of biology that there is a fundamental plan or system of some sort underlying the organic world, and further that the innumerable facts acquired through the study of biology can be properly evaluated only when they are considered in their true relation to this fundamental plan.

It happens that all the theories which have been proposed to explain the interrelationships of plants and animals have been based chiefly, largely, or at least in part, upon the history of plant and animal life as we have learned it from the detailed study of the strata in the rocks wherein are preserved the remains of the plants and animals of ages progressively more and more remote, or upon the development of the individual. It is obvious that the life in any single epoch must have been a continuation of the life of the epoch just preceding, and so on down to the earliest fossils that we know. Because of this time element which has entered into all the hypotheses which have been brought forward to explain the interrelationships of organic life, these have come to be known as theories of evolution.

None of these theories of evolution are in themselves antireligious. During the passage of the years, however, they have been altered and emended and have assumed a narrow, inflexible and dogmatic form which has been presented to the public not as a theory through the application of which the correlation of many isolated facts is rendered possible, but in the form of undebatable truths.

There can be no conflict between true evolution and religion. But dogmatic evolution, which demands the acceptance as established facts of many assumptions and hypotheses which are more than dubious has no place either in science or religion.

This idea was well expressed by Sir Oliver Lodge, who said, "Brilliantly true and successful in their own territory, they [the truths of materialism] are occasionally pushed by enthusiastic disciples over the frontier line into regions where they can do nothing but break down." He added that there is a tendency "to press the materialistic statements and scientific doctrines of a great man like Huxley, as if they were coextensive with all existence. This is not really a widening of the materialistic aspect of things, it is a cramping of everything else; it is an attempt to limit the universe to one of its aspects."

Professor Whitehead has expressed his view of the matter in a different but equally forceful presentation. He said that "Darwin's own writings are for all time a model of refusal to go beyond the direct evidence, and of careful retention of every possible hypothesis. But those virtues were not so conspicuous in his followers, and still less in his camp followers."

Just what is it that furnishes the basis for these remarks? This I shall illustrate by quotations from Professor Huxley's writings; but it might equally well be illustrated by comparable quotations from Darwin. Professor Huxley said that

> it is clear that the result of the comparison of the Miocene and the present Fauna is distinctly in favour of Evolution. Indeed I may

go further. I may say that the hypothesis of evolution explains the facts of Miocene, Pliocene and Recent distribution, and that no other supposition even pretends to account for them. It is, indeed, a conceivable supposition that every species of *Rhinoceros* and every species of *Hyæna*, in the long succession of forms between the Miocene and the present species, was separately constructed out of dust, or out of nothing, by supernatural power; but until I receive distinct evidence of the fact, I refuse to run the risk of insulting any sane man by supposing that he seriously holds such a notion.

Surely no one with any knowledge of biology can find the slightest reason for taking exception to this statement, while those with no knowledge of biology are in no position to refute it.

Had the matter rested here, the theory of evolution would not have met with any serious resistance. But no theory of evolution is tenable which does not consider the relationships of man.

On this point Linnaeus had long before remarked that he had been unable to detect any character by which a man could be distinguished from an orang. Smellie, in 1790, had written:[1]

In the chain of animals man is unquestionably the chief or capital link. . . . From him all the other links descend by almost imperceptible gradations . . . from man to the minutest animalcule. Man, in his lowest condition, is evidently linked, both in the form of his body and the capacity of his mind, to the large and small orang-outangs. From the orang-outangs and apes to the baboons the interval is hardly perceptible. The true apes have no tails and those of the baboons are very short. The monkeys, who form the next link, have long tails, and terminate this partial chain of imitative animals, which have such a detestable resemblance to the human frame and manners.

This is a clear and concise presentation, one hundred and forty years old, of the view-point of a dogmatic evolutionist.

Professor Huxley's treatment of the matter was characterized by strict adherence to the demonstrable facts. He wrote that " . . . whatever system of organs be studied, the comparison of their modifications in the ape series leads to one and the same results—that the structural differences which separate Man from the Gorilla and the Chimpanzee are not so great as those which separate the Gorilla from the lower apes." This is a statement of anatomical facts capable of indisputable proof. Huxley continued,

But in enunciating this important truth I must guard myself against a form of misunderstanding which is very prevalent. I find, in fact, that those who endeavor to teach what nature so clearly shows us in this matter, are liable to have their opinions garbled, until they seem to say that the structural differences between man and even the highest apes are small and insignificant. Let me take this opportunity then of distinctly asserting, on the contrary, that they are great and significant; that every bone of a Gorilla bears marks by which it might be distinguished from the corresponding bone of a man; and that, in the present creation at any rate, no intermediate link bridges over the gap between *Homo* and *Troglodytes*.

He also pointed out not less sharp, though somewhat narrower, lines of demarcation between the gorilla and the orang, and the orang and the gibbon, and noted the complete absence of any transitional forms between them.

While structurally the line of demarcation between man and the great apes, though sharp and distinct, is not so very broad, there are other things to be considered.

Huxley insisted, and rightly, on the structural similarity, which is indeed capable of conclusive demonstration. But he said that "At the same time no one is more strongly convinced than I am of the vastness of the gulf between civilized man and the brutes; or is more certain that, whether *from* them or not, he is assuredly not *of* them." He said further that

Our reverence for the nobility of manhood will not be lessened by the knowledge that Man is, in substance and in structure, one with the

[1] Quoted from Frederic T. Lewis, *Boston Medical and Surgical Journal*, vol. 191, No. 10, September 4, 1924, p. 431.

brutes; for, he alone possesses the marvellous endowment of intelligible and rational speech, whereby, in the secular period of his existence, he has slowly accumulated and organized the experience which is almost wholly lost with the cessation of every individual life in other animals; so that now he stands raised upon it as on a mountain top, far above the level of his humble fellows, and transfigured from his grosser nature by reflecting, here and there, a ray from the infinite source of truth.

Huxley might have added to the possession of rational articulate speech certain other attributes common to all races of men but not found in any of the apes or other mammals.

Perhaps the most interesting of these is the use of fire, which is universal among the races of mankind, as far back in geological history as we have any trace of human remains. Not less interesting is the use of tools, which is also universal. Then there is the wearing of clothes and ornaments, which may be reduced to a minimum but which is invariably present in some form or other in every race of which we have historical knowledge.

But from the non-material standpoint by far the most significant difference between man and the apes is the existence in man of a socially effective sentiment of love resulting in a family life and therefore in conditions wholly different from the promiscuous horde life common, so far as we know, to all the monkeys. Among the monkeys each female is capable of raising her own young, but the raising of a human family requires the ministration of both parents.

Much has been written on the comparison of the sexual life of apes and man, and it has been argued that the family life of man gradually developed from the promiscuous relations of the apes.

But the fact that in man the female is incapable of raising a family without assistance and the existence in all human races of taboos and laws directed toward the maintenance of the family would seem to show that family life was from the first a fundamental human institution. Laws and taboos are not, so far as we know, invented to mold society into a new and preconceived form, but on the contrary to correct the evils recognized as possessing disruptive or destructive tendencies which from time to time appear.

Regarding the fossil history of man, although much has been learned in recent years still no fossil remains have as yet been found which are indisputably those of a missing link. Several such missing links have been described, but all of these have been redetermined by competent authorities as either man or ape or as based on a combination of the remains of both man and ape.

Summing up what has just been said, we must admit the anatomical evidence of the relatively close physical structure of man and the great apes. At the same time we must admit that there exist important and clean-cut differences between them. Further, we must admit that above and beyond mere physical differences man is a being of a nature wholly different from that of any of the apes. Lastly, we must admit that no indubitable "missing links" connecting man and apes ever have been found.

It is apparently incontestable that man is separated by an important gulf from all the man-like monkeys. How can this fact be harmonized with the general evolutionary plan which is so evident as we trace the various types of mammals of the present day back through progressively earlier and earlier epochs to their first appearance in the rocks?

None of these evolutionary lines are quite continuous, for in them there are always breaks or gaps—though often very slight—between successive types and between collateral lines. But in general the lines, so far as the vertebrates are concerned, are obvious, clearly marked and undeniable. The gaps and breaks are to be explained by an application of knowledge gained through the study of mutations and of variation.

We can not deny the actuality of the existence of these gaps, and therefore must admit the lack of perfect continuity in every evolutionary line.

If we assume that the occurrence of the gaps is due to more or less broad and sudden variation or mutation, a phenomenon abundantly in evidence at the present day, then we must entertain the supposition that evolution has not ceased to operate, but is still in progress at the present time.

Between the several groups of sea invertebrates the lines of demarcation are so very broad that it is not possible to arrange these in any sort of evolutionary line. But they seem to fit perfectly well into a geometrical figure (*Journ. Washington Acad. Sci.*, vol. 13, No. 7, April 4, 1923, pp. 129–138) in which each is shown to have affinities with several others, not merely with a single one.

I mention this in order to explain the attitude toward evolution of Professor Louis Agassiz. Toward the Darwinian hypothesis Professor Agassiz always maintained a determined opposition. I believe that this was due to his interest in and very intimate acquaintance with the animals of the sea which certainly can not be made to fit into any scheme predicated on the interrelationships which are found among the vertebrates.

From a perusal of the paragraphs preceding it is clear that in the minds of reasonable people there can be no conflict between evolution and religion. A definite plan and order underlies the entire animal kingdom which thereby is susceptible of interpretation as a unified entity. Evolution has not spent itself, but is still an active force, though whither it is leading we can not even guess. Man is not an ape, and we have no evidence that he ever was.

Personally I am wholly engaged in describing and interpreting the facts of science. Yet I am thoroughly aware that a world expressed entirely in terms of scientific laws and formulae would be an impossible place in which to live. Humanity requires something in addition to the cold logic of ascertained facts and proven theories. Both religion and philosophy are essential factors when it comes to human welfare.

Along these lines Professor Huxley said, "It is worth any amount of trouble to . . . know by one's own knowledge the great truth . . . that the honest and rigorous following up of the argument which leads us to 'materialism' inevitably carries us beyond it"; and further

> If the materialist affirms that the universe and all its phenomena are resolvable into matter and motion, Berkeley replies, "True; but what you call matter and motion are known to us only as forms of consciousness; their being is to be conceived or known; and the existence of a state of consciousness apart from a thinking mind is a contradiction in terms."
>
> I conceive that this reasoning is irrefragable. And, therefore, if I were obliged to choose between absolute materialism and absolute idealism, I should feel compelled to accept the latter alternative.

Professor Whitehead has significantly and truly said, "When we consider what religion is for mankind, and what science is, it is no exaggeration to say that the future course of history depends upon the decision of this generation as to the relations between them."

PERSONALLY CONDUCTED

By Professor NEVIN M. FENNEMAN

DEPARTMENT OF GEOLOGY, UNIVERSITY OF CINCINNATI

MOST of us have traveled. Most of us at some time or other have worried over tickets and baggage and passports and the choice of hotels and strange regulations unknown at home, all made worse by inability to converse in a strange language. Most of us at some time or other have been tired, tired planning, tired dealing with strangers, tired of going, tired of seeing things, tired of everlastingly having new experiences, tired of effort, tired of responsibility. We wanted to be back home, back to something familiar, back to routine, back to the life that did not demand incessant initiative.

Some of us have tried traveling without initiative, traveling in the passive voice, as it were, without planning, without deciding things, without looking forward or backward, sometimes not even looking around very much, personally conducted, hiring some one else to get us traveled. We wanted to get things and places checked off; wanted to say we had been there; wanted the credit that comes from going through the motions. We might even "fake" a church or two, or a famous painting, pretending to have seen them when we had not. A few more or less made no difference to us; the guide may have failed to point them out, and the fault was not ours, so we deserved the credit and had the right to check them off.

Now these two methods of travel, the one in the active voice, the other in the passive, are a parable intended to shed light on our systems of education. American colleges have chosen the second way, the way of the "personally conducted." Its advantages are obvious.

In the first place, more people are willing to take it that way. There are many young people who really have no objections to being educated if only they don't have to worry while it's going on. They have no thirst for knowledge; in fact, it rather bores them. To start out after it alone would be the last thing in the world they would think of, but if there's a good crowd and some one else will do the head-work, selecting the bare minimum of facts to be learned and tell them each day what to do next, they are willing to submit. Anyway it takes very little of one's time, and meantime they are having a good time in other ways. So it's plain that the personally conducted college course has the advantage of appealing to large numbers.

In the second place, it lends itself to organization and quantity production. Fifty students with a thirst for knowledge and a tendency to think, and all raising questions of their own—What could a man do with such a bunch? It is easier to take a hundred, or two hundred, and say: I will tell you what you ought to learn and how to learn it, and when you have enough; and I will make your daily programs and tell you what to think. With such a system well operated there are few troublesome questions.

In the third place, the system favors standardization and makes certification easy. This is the real nub of the argument. Many employers now demand young men with certified educations. Suppose that in order to hold certain positions it were necessary that a man should have traveled. How would it be possible to tell the man who had traveled from the man who had not? It might require half an hour of conversation, or in some cases a whole hour, to determine whether a man had the kind

of culture that comes from travel. It is far simpler to demand his certificate, wherein the guide sets forth—This is to certify that Mr. G. Trotter was a member of my party from such a date to such a date, that he was actually present at the following places (here follows the list); that to my certain knowledge he entered bodily into the British Museum, the Vatican Galleries, the Louvre and fifty-seven other museums and galleries, to wit: (here follows the list); that the days and hours on which he absented himself from the prescribed itinerary did not exceed 10 per cent. of the whole; that he stopped at no hotels not authorized by the management, and that he ate all the meals stipulated except as herein enumerated, and that for the entire tour he is entitled to a grade of C plus. Of course with the itinerary once standardized a simple diploma in Latin might be substituted for a lengthy recital of facts. Such a diploma would at once distinguish the man who had really traveled from the man who had merely gone through Europe to observe, learn and enjoy on his own account.

It is the same way in college education. A man's diploma shows that his bodily presence has been actually accounted for during 90 per cent. of the hours named on a certain schedule for four years; that he has gone through certain motions in laboratories where his presence was required; that he has read certain books in a certain order, dividing up this reading into daily rations as prescribed by the proper authority; that not more than 50 per cent. of the mental work of the curriculum has been substituted by football, basketball, swimming, pitching horseshoes, amateur theatricals and service at the polls in the interest of bond issues.

The argument is urged with some force that the personally conducted college course prevents failures, discouragements, waste of effort and suicide. In European universities, where students are supposed to want knowledge and are treated accordingly, the mortality is notoriously high. Among the crowds that come to college there are many who have not the interest or ambition or moral fiber to work from day to day unless held to their tasks by a constant checking up. There can be no doubt that a system of pedagogic surveillance brings some such to accept a minimum of knowledge who would otherwise fall hopelessly behind and be eliminated. Others are wholly unable to acquire even the modicum demanded by our colleges without daily help. Americans have a profound prejudice against natural selection. There is a widespread feeling that if the student is not actually feeble-minded, commits no grave crimes and pays his tuition, the college is in a manner morally obligated to see that he gets an education.

This prejudice against natural selection is closely related to another consideration, namely, that the personally conducted college is democratic. It obscures the natural differences among men. By meting out a daily ration and spending most of the time checking up, we hobble the man who might otherwise run and drag the man who is unable to march. Thus the whole company is kept together and one man is as good as another. From a distance the company looks imposing and makes us feel like singing "Like a mighty army moves the church of God." It's only when we get up close and look at individuals that we see that neither the best nor the worst are doing what God made them for.

It is a well-known fact that American practice in higher education differs radically from that of Europe. America treats the student as a child; Europe treats him as a man. We decline to assume that his desire for knowledge is real and dominant. We watch him at every turn, check his attendance at

every class hour, assign him daily tasks, test him at short intervals to make sure that he works, tell him whether and when and how and how much to play football, decide when he needs help and press it upon him. The professor, instead of devoting himself to those who can and will, spends most of his time on those who either can't or won't. Rather than see students exposed to heresy we turn the lights out.

In Europe the student is taken at his word as a seeker after knowledge. He is given opportunity instead of surveillance. Often the assumption is wrong, the confidence misplaced and the opportunity scouted. The percentage of failures is high. None the less the man who can and will is saved, and freed from the drag which our lockstep system imposes. The European system frankly avows that men are not born equal. As for freedom, the European university is the freest place on earth, but it is not democratic except in opportunity. The American university clings to equality, which it insures by the sacrifice of freedom and by systematized mediocrity. It is inherent in our system of personally conducted education that the distinction between able and unable, zealous and careless, is obscured. Thus we parade our democracy like a watch in a gold case, while leaving out the mainspring, individual responsibility.

Our squeamishness at natural selection in the educational field is curiously out of harmony with the philosophy of individualism which still dominates our ideas in the commercial and professional world. America still admires a Henry Ford and worships a Lincoln and does not squirm at the thought that their competitors with equally good intentions received less reward.

Equally is our management of higher education out of harmony with our vaunted admiration for sportsmanship. Theoretically, we like a man who plays the game and asks no odds and does not squeal when hurt. Practically, we prefer to debase the university system rather than permit the incompetent and listless to bear the penalties of their limitations or faults.

The effects of this system might be borne with equanimity so far as they concern the unable and the unwilling. It is in the sacrifice of the able and willing that the injury becomes deplorable. The student is generally a grown man. The ostensible reason for his presence in a class is the desire for intellectual attainment. The ostensible task of the instructor is to cooperate with the student in his efforts. The ultimate responsibility is on the student. With such a relation, there is no need for surveillance, coddling, threats and everlasting admonition. These things become necessary only when the motive of intellectual attainment becomes subordinate to other motives. Then, according to the American system, responsibility passes to the instructor whose duty it is to furnish substitute motives and "get the class through." Such motives take the form of fear and hope of grades and credits based on compulsory tasks closely supervised and stimulated by constant prodding and threats in the form of tests. Generally a charge account is opened, with assignments on one side and grades on the other, and there is a regular system of bookkeeping by which the student may know from time to time whether his balance is in red or black. Much of the instructor's time is spent in getting red balances into black. The disproportionate amount of interest devoted to this borderland where red meets black affects the character of the instruction and withdraws attention from the real students whose solvency is beyond doubt.

Necessarily the relationship between student and professor under such a system is wholly different from that which

prevails where the professor's first concern is to cooperate with those who are seeking knowledge. The inspiration of companionship is lost and even those students who are capable of better things accept the situation and come to look upon the state of their charge account as the thing that matters most.

The damage to the better student is twofold, and great on both counts. First, his scholarship is limited and, second, he fails to acquire that intellectual sincerity which is fundamental to independent work and leadership. If the university fails to develop intellectual leadership there is poor satisfaction in a long roster of lame ducks who have been nursed and coddled and threatened and driven and dragged along just far enough to save the institution's face, and then turned out to begin work, as they should have done four years earlier.

PROGRESS

By WILSON D. WALLIS
UNIVERSITY OF MINNESOTA

THE word "progress" was first used in the modern sense by Lucretius, a Roman writer of the first century B. C. It means literally "going ahead," its contrary being "retrogression," "going backward."

Lucretius believed that the evolution of human society exemplified progress, although he recognized that some of the changes which successive centuries had witnessed were not improvement. Considering social evolution in its broad sweep, he says in effect, man has made progress, but here and there he has retrogressed, or has stagnated, rather than progressed.

Though no comparable view of evolutionary progress is found in the civilizations which antedate Lucretius, most of them had a concept of progress. They believed the highest good had been realized in the earliest stages of man's life, in the paradise or elysium in which men lived before they embarked upon social and political evolution. They therefore viewed the reattainment of an earlier status as progress. A harking back to an earlier status was, to be sure, retrogression in the sense that it was a retracing of a course traversed in pain and sorrow, but it was progress, so at least they thought, in the sense that it was the way to attainment of the better life. Thus even those writers who bemoan the passing of better times have a concept of progress, otherwise they could not depict man as degenerating.

Contemporaries have attached various meanings to progress. To some it means merely the continuation of processes already under way. The term as used by them may connote mere continuance of a movement, force or activity, or merely an increase in the momentum of a phase of social life.

Thus a nation is said to make progress in manufacturing, road-building, imperialism, and so on, when these activities are carried on with increasing zest and success. But this concept is too narrow, for quantitative or linear dimensions can not measure progress. Many a town or city boasts of "progress" in population, meaning that the number of inhabitants is increasing; but whether the increase in number of inhabitants really indicates progress depends upon various conditions.

Or one says that a community makes progress in wealth, meaning that the valuation of taxable property or of bank clearings is increasing; but this too must be interpreted in human terms before one can ascertain whether it indicates progress. A mere quantitative increase is as such a mere quantitative

increase, and it does not necessarily indicate progress. If men are no better off there is no progress, there are merely more men who are no better off; and if dollars increase but human weal is no greater because of human wealth, then, too, there is no progress.

Others use the term "progress" to indicate approach toward a goal, explicit or implicit. In any helpful sense of the term, no doubt progress implies a goal, and, indeed, something more than a mere goal. A disease may be said to be moving toward a goal, but to the extent that it is attaining its culmination the patient is not making, but is failing to make progress; the patient is making progress if he is thwarting the disease. Progress, then, implies at least a desirable goal and this means more than merely a desired one. It means a goal which embodies a desirable end and one which, in the long run, brings satisfaction. A desirable goal, therefore, presupposes a choice of goals, a choice made with discrimination and a knowledge of means as well as ends, and choice, in turn, involves evaluation. There must be also a weighing of means, for in choosing the goal one is also choosing the means to it; and when a man or a culture chooses wrongly, "life and the consequences of the wrong may not ask as to intent," but merely demand the penalty.

Progress, then, implies choice of a desirable goal and of adequate means for attaining it; and the highest progress involves the choice of the most desirable goal and the best means of attaining it. But interpretations of conditions underlying progress have varied widely.

Some have regarded progress as resting in the hands of fate, destiny or inevitable historical forces. Everywhere, it has been said, man struggles with nature, and in every culture he desires to improve his lot.

Even in the remotest periods of prehistory there was a struggle for the conquest of nature and for the accumulation of goods. Early Stone Age man improved the crude stone implements of predecessors, and each generation, or at least each millennium, added something to the achievements of predecessors. Thus, without knowing it, he who struggled with circumstance helped to bring the modern age.

Retrogressions also are regarded by some as inevitable. Man may struggle, but he does not always plan wisely or execute efficiently. But though setbacks are real, they are temporary and should not occasion discouragement.

Given things as they were, we are assured, events could not have been otherwise, and men could not have acted differently. We may admire the torchbearers of the Renaissance, but granted the opportunity, the response to the inspiration was inevitable. The Industrial Revolution might have come earlier or later, but come it must; and given things as they were a century ago, a Civil War in this country was inevitable. The World War, similarly, grew out of antecedent conditions; it might have come earlier or later, but come it must.

With regard to the invention of mechanical devices a similar conclusion is drawn. But for a happy concourse of events and personalities the radio might not have been invented for another decade, but invented it would be, once man had advanced to a certain point in science and ambition. Thus inventions, we are told, are inevitable, once culture has attained a certain status of accumulated science and technology.

In support of this position attention is called to the fact that certain discoveries and inventions can be predicted with a slight margin of error. Perhaps there is no general progress, but only progress in certain fields of activity. However that may be, progress in one line is not an isolated phenomenon, but implies progress in related lines.

Progress in technology, for example, has been preceded, accompanied and fol-

lowed by progress in trade, science, specialization, and an assured, that is, a dependable interdependence, without which any considerable specialization is impossible. Thus the Industrial Revolution has been intimately bound up with advance in trade, science, technology, a credit system and internationalism, and advance in any one of these was always to some extent dependent upon advance in the others. Hence social progress, however strictly interpreted, involves progress in some larger sense, as, for example, in political life; and this in turn is bound up with economic and industrial organization, technological development and with communication and the dissemination of information. A change in any one of these may have far-reaching effects in the social world, as witness events which followed the development of the printing-press, the railroad, the telephone, the telegraph, the radio, the aeroplane. Thus the problem of progress is many-sided, and it becomes increasingly difficult to fathom as civilization becomes more complex. Social life, for example, is a phase of a specific civilization, and it is therefore dependent upon a specific culture. But, as history testifies, civilizations rise and fall. Must, then, every civilization, after a certain period of development, fall and pass off the stage?

If such be the case, what limits does this necessity impose upon the possibilities of social progress? In addition to the apparently limited life of a civilization, there may be within a given civilization certain specific limitations upon progress. Greek civilization, for example, seemed capable of making great progress in literature and the fine arts, but it was weak in national and international politics, and in the domain of technology; and perhaps it was destined to make no notable achievements in other domains. Another possible limitation upon progress arises from the fact, if fact it be, that along with the seeds of good are sown the seeds of evil, so that in any culture which is advancing there is a contest between the forces which make for progress and those which tend to thwart it. Witness the increase in crime, disease and war which have been the invariable accompaniments of progress.

A primitive culture is comparatively free from these untoward tendencies, but a developing civilization must cope with them at every step. If these are necessary evils, then, it seems, a bane is inherent in progress. Indeed, perhaps progress is necessarily dangerous.

Consider, for example, the development of transportation. With canoe and the dug-out there are few dangers; the sailboat is a step in advance, but it brings added dangers, and the steamboat intensifies these in a thousand ways—think of the *Titanic*. In the ox-cart we travel slowly but safely; in the horse-drawn vehicle we make more rapid progress but encounter greater dangers from steed and speed; in the automobile we hurl our bodies through space with locomotive velocity, and there is some danger of hurling them straight to heaven or hell; in the aeroplane we fly faster than the swiftest birds, but the danger from a somersault or a nose-spin is greater than the danger from a hurtling automobile.

Do these dangers typify a tendency which is inherent in progress? Certainly they seem to be an accompaniment of many phases of it.

Internationalism has grown, but it has brought a larger number of possible and perhaps of actual entanglements. The larger the number of nations with which we have relations, the greater the possibilities of friction and enmity. Meanwhile war itself becomes fraught with greater danger to all participants.

In using instrumentalities we become dependent upon them and to that extent

place our fate beyond our immediate control. The Erewhonians discovered this danger and they therefore rigorously excluded all machines from their civilization. Is there not a grain of realistic truth in this ironic fancy of Samuel Butler? Are we not annually more dependent upon our machines? And is it not true that we work for them as well as they for us?

Finally, there is the possibility that a civilization, particularly our civilization, may become too complex to cope with the resulting problems. With all our boasted ingenuity and science we are almost fundamentally ignorant of the character of our civilization and of its trends. Although human presumption knows few bounds, no one presumes to understand contemporary civilization. At most, one claims but small knowledge of a small field. We do not know where we are going; neither do we know that we are on our way. If there is a desirable goal somewhere in the future, then we may be far out of our way.

We have given tremendous impetus to our culture and have specialized and intensified it in many ways; now our problem is to keep up with it, and little time is left us to inquire whither it leads. Nor can one be confident that the most leisurely inquiry would make us much the wiser, for the course of culture is difficult to predict. The goal, if there is one, seems to be somewhere the other side of nowhere.

THE KING OF MUSICAL INSTRUMENTS

By Professor ARLAND D. WEEKS

NORTH DAKOTA COLLEGE, FARGO

WHILE no violin census has ever been taken, the number of these instruments in existence is immense; the realm of the violin is wide. Unlike the automobile, which, produced by the million, goes into the discard by the million when used for a brief span of years, a violin is cherished the more tenderly with each passing year, mileage increases its value, and century-old models top the market. Tens of thousands of violins are imported into the United States of America annually, at a tariff of one dollar each and 35 per cent. ad valorem, and factories and individual workshops within our borders add to a yearly output as nearly approximating immortality as any object of commerce knows. Ships become obsolete; fine furs are ravaged by moths, faded by the sun, worn by rubbing against show cases; garments go out of style; the gold watch grandfather handed down is replaced by a thin one. Change and decay is all around—except in violins.

Death rarely comes to the violin. Have you ever heard of a violin being thrown away? Search the ash cans and dumps of our cities, and not one. Occasionally, to be sure, a fatality occurs, as when a player in an orchestra has his violin collapse in his hands, or when a fire destroys, as in the instance of the Stradivarius left in his room by a young man near Lake George some forty years ago, and known to have perished in the flames that consumed the residence a few hours later. Moisture may cause a violin to fall apart, while intense heat may damage beyond repair. Some may be lost, crushed or abandoned, often needlessly, as not capable of restoration. But authentic cases of the passing of violins are few and far between. Old age is coveted by the king of instruments, and the teeming realm adds numbers yearly, nay, hourly, a fact that implies a stress for a place in the sun. Will not the world become overpopulated with violins? It is inconceivable that the new violin, from the violin-making centers of France, Germany, Austria, England, and from individual producers in the United States in cities and villages—Atlanta, Minne-

apolis, Duluth, New Orleans, Cincinnati, Grand Rapids, Scranton and Coffeyville, Kansas—should not encounter a sales resistance and a toxic condition of the marketplace from the sheer weight of numbers. The instalment plan of selling the king of instruments, in effect with the leading music houses, bears testimony to the stress. No human population can advance at the rate of augmentation possible with a musical instrument that lasts practically forever.

Among the stresses and strains (not musical), which threaten less than peace in a supposedly harmonious realm are those of the new versus the old makers. The shops of the makers of one, two or three centuries ago in Italy and mid-Europe were as filling stations in the suburbs for numbers. There were great master makers, the Guarneri, Stradivari, the Guadagnini tribe, the Amati family, Bergonzi, Storioni, Maggini, the Gaglianos, Montagnana, Tononi, and scores of other well-known names, and in addition, the ubiquitous amateur. The old makers acquired a reputation for the production of beautiful and pleasing instruments. Cremona, northern Italian city where violin-making reached its climax by the middle of the eighteenth century, became as it were a sacred city, and where Stradivari once sold his best violins for twenty-five dollars the violin-crazed tourist pauses with bated breath. The old makers gained an enviable reputation in their own day; they have a marvelous reputation in our day. But whether such high repute to-day is based on musical values wholly or partly on tone and partly on zest for antiques is another matter.

The makers of new instruments to-day—and let us remind ourselves that the Cremonese violin was once new—claim that the modern-made violin, of the best type, is fully the equal of the old instruments. They say that the violin-using world must come to the use of the new violins: that the old ones are becoming weak and worn, that the fibers are losing their power to vibrate, going dead in the players' hands. The famous Cremona tone is declared to be sweet but weak. Tales are told of players with expensive old instruments who are compelled to exchange them for powerful modern instruments in order to hold their positions as musicians. Moreover, probably a heavy majority of all old instruments have been repaired or reinforced to make them more suitable for modern use. In the time of Stradivari playing in positions was unknown and the violins were tuned low. The necks of the old instruments must be lengthened for use to-day, and few of the instruments can be used without strengthening parts, especially the top plate. Ninety-five out of every hundred of the Stradivari violins, of which hundreds exist, carry reinforcements of patches and glue cunningly placed within.

The first struggle within the peaceful empire of the monarch was for power, and the palm for that goes to the modern violin. Charles Reade, the novelist, eminent judge of old violins, writing sixty years ago, said, "At present there are more scientific and intelligent Fiddle Makers than ever existed at Cremona." Reade gave the Cremona an advantage in sweetness, oiliness, crispness and volume of tone as distinct from loudness, but awarded the modern instrument superiority in power. Since Reade's day there are modern makers who claim the tone distinction of the old instruments together with power. Played behind a screen in a western city a master instrument of Joseph Guarnerius del Jesu and a violin by a local maker left an expert in doubt as to which was the priceless Cremona and which the handiwork of an American maker, below whose shop motor buses and street traffic roared. The chief of makers was the grand old man Antonio Stradivari (1644–1737), who produced by his own hands the wealth of a multimillionaire.

Disconcerting is it to find Ole Bull saying of the Stradivari violin: "But although the tone is wonderfully even and full, it is tinctured with a peculiar nasal quality. For this reason, though I have owned several fine specimens of this maker, among them one of the quartette made for the court of Spain, I have never played on them in public."

The layman would think it an easy assignment to find out whether the old Italian instruments are actually superior to the best of modern make. Let a word be breathed in confidence into the reader's ear: there is no field of human activity—not even in the rich and hoary institutions of religious tradition and sentiment—in which there is less of the strict ascertainments of science than in the violin world. Let one set out to glean the facts of comparison and he will return almost empty-handed, but he will have plenty of impressionistic views. Suggestion runs riot in violin land, where tone is heard by the eye, and acoustical properties are reflected by labels. Word came from the University of Iowa of tests of violins. By resonators is found—what? That good violins are better than poor ones; but nothing to help resolve the problem of comparisons of the new with the old. If one would have the truth about the old and the new he must needs proceed with full care to exclude suggestion, capturing the elusive fact, perhaps in the sieves of acoustical laboratories; only the world would then be the poorer through having lost a rich province of romance. Great artists use great old violins. Well, perhaps the audiences expect it, and again, do they always use them?

But as to appearance, the internecine strife between the new and the old varnishes is reported as definitely in favor of the old, with, however, here and there an announced contender in fighting mood. Connoisseur Reade, the one-time premier expert of England on Cremona violins, gave the case entirely in favor of the old varnishes; this after daubing varnish himself for years. The art of glorious varnishing rose, and fell. Before the year 1800 the divine fires of the varnish of the Cremonese makers, and of old Jacob Stainer, who also knew his varnish, had passed. Spirit varnish, stiff with resin, made its stultifying appearance. The varnish mystery of Cremona is still a mystery; the air is filled with conjectural explanations, skepticisms, counterclaims and present-hour assertions of formulas as good. It is all a maze. But who knows but that the antiquarian of three hundred years hence may rave over to-day's violin, sprayed with Lako-Duke, as the ne plus ultra of finishes? But let us be reverent. The writer for one, however, is free to confess that he, until he knows something about what others think beautiful, is a shade uncertain himself. Let the ancients and moderns continue if they must the fight of the formulas for the ideal appearance of the violin exterior. In one phase of the general strife victory may at once be accorded to the old—there can never be any more violins made at a time now long passed. The supply is limited. Once an old violin, always an old violin, whatever the tone, whatever the varnish.

But sometimes a new violin is also an old specimen; its label says so. Oh, had there been a pure food and drugs act in force upon the violin-makers who promptly saw a commercial advantage in labeling with distinguished names, flooding the world with misbranded, short weight and adulterated products! Not only were the names of distinguished makers pasted in the interiors of terrible fiddles, but the names of even minor makers were profusely plundered. Makers like Friedrich August Glass and Hopf (any one of the Hopfs will do) were made to lend their names to handicraft that left much to be desired in tone, model, outline, varnish, sound holes, purfling, bass bar, corner blocks,

scroll, finger board and graduations. Trade probably is not acquainted with a more extensive sweep of deception and false labels than appeared in the making of violins. Unquestionably, millions have believed that they had a genuine specimen of a maker when such they had not. It is evident that the genuine violins of the old makers were limited in number; but under the guilefulness of past years this number was made to appear hundreds of times as large. Ah, the struggle between the true and the false in violins has been, still is and ever shall be. Sad scenes too. David Laurie, canny Scot connoisseur of violins de luxe, tells of a refined and elderly Frenchman who fell sick and died soon after being convinced that an estimable violin, long in the family and believed to be a genuine Stradivarius, was not that master workman's product. At least one man traded a farm for a Stradivarius, by name; value, as adjudged by Chicago musical instrument intuition, eighty-five dollars. In Spokane, after pursuit across the country, was found a "Stradivarius" which had been included in a state's exhibit at the St. Louis Exposition; behold, a commercial violin of mean workmanship, darkened with seamy varnish and not even old. But probably thousands had paid this flimsy fraud the tribute of awe-tinctured gaze. The other day a newspaper reported the existence of a Stradivarius in a proud owner's possession, the instrument bearing the date of 1600, or forty-four years before the birth of its putative maker. The printing of labels must at one time in violin history nearly have equaled in extent the violin industry itself. It would be a gain if a few hundred thousand worthless old fiddles could be collected and used for parts and for kindling wood. Then modern makers would have a wider market, the old master makers could lie still in their graves and the public would be spared an amount of anguish from catgut and wire ill assorted with a sounding box.

One can not fail to sympathize with the regal instrument in its load of responsibility for keeping itself regal. Low-born specimens, variants from the ideal prototypes, are many and obtrusive. God never made so many different woods and qualities of materials as there are different kinds and qualities of violins made out of the trees. Human skill and lack of it have a way of transforming materials into a wonderfully wide range of excellence. No two violins, even by the same hand, are quite alike. The master makers were always trying to better their work; they presumably became tired of doing exactly the same things, and introduced variations of edges, corners, bouts and arching. No two violins on the face of the earth are precisely alike in sound, in which respect they are like people's voices. Did you ever hear two persons who spoke exactly alike? And one recognizes in a person after years have passed, after change of place, after sickness or misfortune, individual qualities of voice; so with violins. The bridge may be lowered and the sound post reset, the angle of the finger board may be altered and even the violin's insides may be modified, yet the tone is likely to be recognized as the one belonging to the instrument in its unregenerate or original state. The writer recently examined two instruments of a well-known American maker; they were as alike in appearance as two peas; their dimensions were exactly the same: thirteen and fifteen sixteenths inches long; same height of sides, same arching, same width of bouts, same everything. Heard together one could be distinguished from the other; there was a close similarity of tone, but one had a slightly fuller tone and more volume in the lower strings. With seventy parts, each of

which may vary infinitesimally in size, density, quality of wood, and with adjustments differing at least minutely of bridge, sound post and strings, with varnish perhaps not always from the same kettle, is it any wonder that many as violins are they are never twice wholly the same? Only a mathematician could calculate how many permutations and combinations of sound qualities would be possible through differences among seventy parts. Violins will be twice alike when two human beings are.

Beyond congruous and casual variations of construction lie avowed differences of practice among makers and of opinion among bystanders. By design sound holes are varyingly spaced, the length and proportion of parts established and thicknesses of wood caused to vary. Take a violin to an expert and he may thumb the top plate and say the graduations are too thin, while his brother expert may thumb the back and declare an unhygienic thinness appears there; another shakes his head over the non-symmetry of the veining of the spruce of the top, and still another eyes askance a bass bar not of uniform depth throughout its length. The amateur, depressed, may learn that he has overprized his violin, that not all the instruments made by good makers are good and that fine instruments have been ruined by attempts at improvement on the part of unskilled repairers. For peace of mind the owner should be chary of confidences, for here suspicion may be cast on the impeccability of one's violin, or one may encounter coldness in the man set on a different model. While disagreements may not amount to riot or insurrection, yet the hubbub of unlikemindedness is bound to unsettle the sensitive and disturb any who have not achieved the peace of dogmatism.

The king of instruments is scheduled for some disharmony with the sound physicist, who says the violin is almost an accident and could really be greatly improved if Fordlike intelligence started in that direction; who calls attention to the wolf notes, and to the different qualities of open and of stopped strings, and declares that the instrument is inexcusably weak as a sound producer; who says the effect of the mute on tone reveals that the bridge is pretty nearly the whole show (as if the effect of a flat tire goes to prove that with automobiles tires are pretty nearly the whole show). The early violin makers, we are told, were merely experimenters and rule-of-thumb workers, governed not by principles of sound production but largely by a mechanical opportunism. Thus, the incurving of the middle bouts is a necessity for the play of the bow, and what does it have to do with ideal sound production? The violin has been fitted to the player's convenience, its evolution as a sound box being thus limited. And if varnish is good for the outside, why not for the inside of the instrument? Give the acoustical engineer resources and commission him to improve the violin, and the time-honored canons of the luthier's art will go by the board, so is it said. To be sure, it *is* surprising that while epoch-making advance is made in surgery, architecture, costuming, sound transmission, seismography and heating plants, the most proficient violin-makers of to-day merely imitate craftsmen of two centuries ago. In what other field of human endeavor did early craftsmen command an ultimate science? There is not a violin house in the world that does not advertise imitations of this, that or the other violin masterpiece of two or three centuries ago. It may be all right, but——. The violin changes less than theology.

But on the whole the rule of the king seems fairly well assured. Lately tens of thousands of high-school pupils have taken to the violin as it is, in school orchestras. In the cliff-locked depths of the Canadian Rockies one descries at a distant cabin door a sprawling specimen

of humanity, a young male, holding a violin of light yellow hue on his right knee. In candle light in the rude homes of "our contemporary ancestors" of the Kentucky mountains young men play fiddles while others tap rhythmically on the fiddle body with a neat little stick of pencil size. The bush farmer of northern Minnesota "takes a tune" out of his violin while the blasts of December howl and the coyote yells. The king stands well in the hearts of his subjects, and none of his compeers can win such tributes as that paid to the violin when the playing of it brings tears to the eyes of the one who plays.

It can scarcely be expected, with thrones tumbling in an age of ruthless realism, that the long and heretofore essentially peaceful rule of the king of instruments will forever stand immune to the leveling tendency, which might take the form of a moderation of language of adoration. A pronounced rhetorical stress appears as between the exalted and perfervid terminology of ecstatic devotion and the sordid vocabulary of reference of those animated by irritation or by prejudice of the violin's occasional low associations. Even the prince of fanciers, the great Reade himself, did, in his "Petition to the Lords of the Treasury," in which he sought a lower dutiable valuation on his Italian violins, refer to the sacred substance of these as "carcasses," the instruments imported being more or less in a knocked-down form. The word *fiddle* is no such word as *violin*, the latter one of the handsomest words in English. If Nero fiddled when Rome burned—derision and hardness; if he played the violin—sublime poignancy! Any one inured to the rainbow vocabulary of real estate promotions and of complexion specialties might come unscathed through the literature of the violin, including the catalogs of old and rare instruments. Even an encyclopedia article may contend, in an age of philosophic doubt, that the violin at least has a soul. It is unlikely if in all the literature of romance and damsels there is a finer assortment of luscious adjectives than have been applied to the violin; to its moving tone, brilliant, mellow, responsive, flexible, fascinating, silver, glorious, bell-like, splendid, sweet, flute-like, far-carrying, charming, exquisite; to its appearance and varnish, golden brown, handsome, rich red, plum red, magnificent, gold red, artistic, masterful, distinguished, bold, elegant, venerable, plum-orange-red, delicate, mighty, marvelous, perfect.

Long live the king!

CORN-STALKS AND COBS IN INDUSTRY

By L. K. ARNOLD

ENGINEERING EXPERIMENT STATION, IOWA STATE COLLEGE

FROM hard, dense, strong material resembling polished ebony to a soft, spongy material resembling cork is the remarkable range of synthetic wood-like products produced from corn-stalks.

For the magic wand of research has waved over the great waste fields of corn-stalks, corn-cobs and straws and there have stepped forth materials that vie in beauty and utility with the finest products of our great forests. Once more the chemical engineer has taken the waste and despised things of the world and is creating from them new products for the comfort and enjoyment of mankind. Already factories are springing up out in the great middle west to bring these things into a practical reality and the farmers are looking forward to an income from otherwise waste materials. The lowly corn-stalk at last is coming into its own, where it will rank with the grain in giving value not only to the farmer but to the world.

The development of this great industry of the future is largely the outgrowth of years of patient but enthusiastic research by the department of chemical engineering and the Engineering Experiment Station of Iowa State College in an effort to be of real service to the middle west by utilizing the vast quantities of agricultural wastes. From dark, wet laboratories in the basement of the chemistry building to a new building designed especially for the department, equipped with the most modern and complete semi-commercial wall-board machinery of any laboratory in the country is one of the steps in the development of the work.

The importance of the project has secured federal support through the U. S. Bureau of Standards, which furnishes four technical research men and part of the necessary equipment. The agricultural engineering department of the college is cooperating by developing the necessary machinery for harvesting the stalks.

To the technical man the production from corn-stalks of the products ordinarily made from wood is not so extraordinary or mysterious as it might appear at first glance. To be sure, corn-stalks differ outwardly from our usual pulp woods. The slender stem of the corn-stalk varies in height from eighteen inches to twenty-four feet, although the usual height in the corn belt is from six to ten feet. It is made up of the hard outer shell surrounding a center of soft pith. This outer shell is made up of a large number of bundles of long slender fibers and tubes known as fibro-vascular bundles. These fibro-vascular bundles are also found running through the pith. Every eight or ten inches along the stem long slender leaves branch out. At these points the branching of the fibro-vascular bundles going to the leaves forms the hard dense portions of the stalks known as nodes. The soft absorbent pith is made up of flat, non-fibrous cells.

The framework of the corn-stalk, as in most plants, is cellulose, which constitutes about 45 per cent. of the total weight, as compared to the various woods containing 48 to 62 per cent. The lignin content of corn-stalks is about 31 per cent., compared to 23 to 34 per cent. in

various woods. Corn-stalks are characterized by their high pentosan content of over 27 per cent., in contrast with the common woods, which range from 7 to 25 per cent. Apparently there is very little difference between the chemical composition of the pith and outer fiber although they have widely different physical characteristics. The leaves run slightly lower in cellulose content than the stalks or husks. The cobs also run slightly lower in cellulose content and higher in pentosans. From analyses it is evident that chemically corn-stalks and cobs are not greatly different from wood although of considerably different physical properties.

The long, strong fibro-vascular bundles and the short broad pith cells of the corn-stalks are torn apart by shredding and beating in a water suspension in a paper beater or rod mill. By the time they are of the proper length they have absorbed a great deal of water and become slightly sticky on the surface, so that when pressed in a mat and dried they hold together in the form of a board. By cooking under pressure this property of sticking together is increased. The fibers are formed into the board, pressed and dried on continuous machinery.

The use of boards such as these in construction work has developed rapidly. A few years ago wall boards and insulating boards were considered only a material for use in temporary partitions or cheap repair work, while to-day thousands of square feet are going into the construction of houses of the better class. The older type wall boards are made up from paper pulp or waste paper and resemble sheets of heavy cardboard. The gypsum wall boards have a core of gypsum plaster faced on both sides with heavy paper. The insulating boards, with the exception of cork board, are made up of a mat of long fibers felted together into a relatively soft board about one half inch in thickness. The fibers are held together firmly enough to produce a board of sufficient strength but not so firmly as to eliminate the tiny air pockets and the surface air films on the fibers which give the board heat-insulating properties superior to the other boards. A great variety of raw materials have been proposed for insulating board manufacture, some of which are being commercially utilized. Boards are made from such materials as wood, wheat straw, flax straw, cork, sugar-cane waste, licorice root waste, and other wastes.

The corn-stalk insulating board is suitable as a substitute for lath and plaster, as a plaster base, or as sheathing either under wooden siding or under stone or brick veneer. It is an excellent heat insulator so that its use as a lining for refrigerators has been studied. Boards from 2 to 2½ inches in thickness have been built up by cementing or stitching together a suitable number of the 7/16- or ½-inch boards and by forming thick boards of a single layer on a special suction machine. Material equal to cork board in heat-insulation value has been produced and shown to be satisfactory substitute for the higher-priced material.

A hard dense type of board has been produced with the simultaneous application of heat and pressure in a special type of hydraulic press. This board resembles a very hard grainless wood and is suitable for many uses, such as paneling construction in Pullman cars, automobile bodies and truck bodies. Another type has been produced by pressing dry board under high pressures. This material resembles ordinary lumber.

But insulating board is only one of the things which can be made commercially from corn-stalks. Corn-stalks are now being used commercially in the production of excellent grades of paper. This

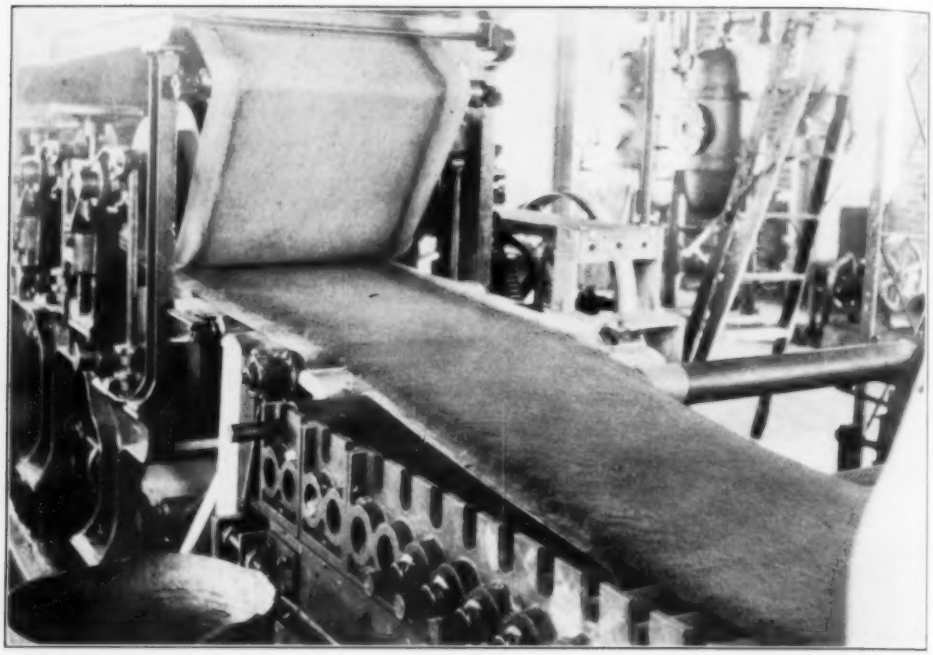
CORN-STALK HARVESTING MACHINE

DEVELOPED BY THE AGRICULTURAL ENGINEERING DEPARTMENT, IOWA STATE COLLEGE.

is the outgrowth of centuries of effort by inventors. In most of the older methods an attempt was made to separate the outer shell and pith. In this manner good paper was produced but not at an economical cost. At Iowa State College the entire stalks have been made into paper without any attempt at separation of parts. Practically all the standard methods for producing paper pulp have been applied to corn-stalks in the laboratory. Hundreds of experiments in which small batches of shredded stalks have been cooked with varying pressure, varying length of time and varying concentrations of chemicals

PILING BALED CORN-STALKS

FOR USE OF THE CHEMICAL ENGINEERING DEPARTMENT AND THE U. S. BUREAU OF STANDARDS. (MACHINE DEVELOPED BY THE AGRICULTURAL ENGINEERING DEPARTMENT, IOWA STATE COLLEGE.)



—Photo from the U. S. Bureau of Standards

CORN-STALK WALL-BOARD LEAVING PRESS ROLLS TO DRIER

CHEMICAL ENGINEERING LABORATORY, IOWA STATE COLLEGE.

have been carried out. Each batch of pulp has been beaten, refined, screened, bleached and made into small test sheets on miniature paper equipment. As a result it was shown that good paper could be made by various chemical processes. Excellent paper of the type used in books and as writing paper can be produced by what is known as the "soda process," in which the stalks are cooked in a solution of caustic soda or lye. Paper produced by a modified soda process known as the Dörner process is now on the market. A good brown wrapping paper can be made by the Kraft process. Processes are also being developed for the production of a cheap mechanical pulp suitable for newspaper use.

By further purification of the paper pulp alpha cellulose can be produced. This is the raw material for rayon, or artificial silk, and is at the present time produced from wood and cotton. Experiments at Iowa State College showed that viscose could be produced from corn-stalk alpha cellulose, but due to lack of suitable equipment no extensive studies were made. Experimental work by a commercial organization in an eastern factory showed that high-grade rayon can be made by the three methods in common use in the United States.

The possibility of utilizing corn-stalks to replace wood as a raw material in the paper industry is of particular interest because of the rapidly decreasing supply of wood available in the United States. The great virgin forests which in the time of our forefathers stretched from the Atlantic Ocean to the Mississippi River and fringed the shores of the Pacific Ocean and the Gulf of Mexico are to-day so depleted by the inroads of the pioneer, the lumber man and the paper man that the future sup-

ONE-TON BEATER

USED IN BEATING CORN-STALK WALL-BOARD PULP.
CHEMICAL ENGINEERING LABORATORY, IOWA STATE COLLEGE

ply of wood for various uses is very uncertain. To be sure, some wood is being grown, but it is hard to convince the American business man that the growing of trees with all the hazards of storm, fire and disease, for a low return sometime in the distant future is a desirable business venture. As a result, four times as much wood is being used as is being grown. Wood for paper pulp is especially scarce, since the paper mill with its expensive layout of equipment can not, like the saw mill, follow the retreating forests back. In excess of 55 per cent. of all the 9,000,000 tons of paper used annually in the United States is imported as paper, paper pulp or pulp wood.

Corn-stalks as a raw material for paper and insulating board have the advantage of being an annual crop available year after year. The annual production of corn-stalks in the United States is estimated at 150,000,000 tons. In the corn belt they are concentrated in large quantities over relatively small areas. In Iowa, for example, one third of all the land is planted to corn each year. In parts of the state as much as 60 per cent. of the land is in corn. It is estimated that the average yield of stalks is at least 1.5 tons an acre. On this basis, using the state average of one third the land in corn, a plant operating 300 days per year could secure eighty tons of stalks per day from over a five-mile radius, or 335 tons per day over a ten-mile radius. In that portion of the state where 60 per cent. of the land is in corn a radius of five miles will yield 150 tons of stalks per day, and a radius of ten miles will yield 600 tons of stalks per day. It is evident that the length of haul for even a fairly large factory would be short.

Methods for harvesting of corn-stalks have been studied by the agricultural engineering department of Iowa State

—Photo from the U. S. Bureau of Standards

SHREDDER USED IN SHREDDING CORN-STALKS FOR WALL-BOARD

CHEMICAL ENGINEERING LABORATORY, IOWA STATE COLLEGE

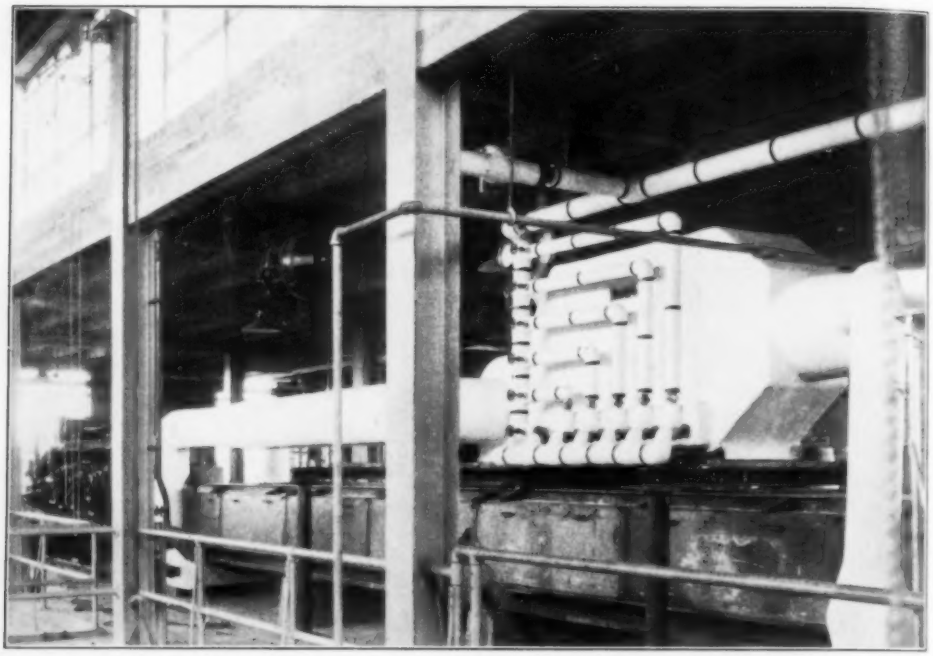
College. As a result of these studies a machine has been built which both cuts and bales the stalks as it travels through the field. This machine is a combination of a mower, a hay loader and a baler built into one machine drawn by a tractor. The stalks are cut by the mower, elevated from the ground to a hopper over the baler by the hay loader, and baled in the baler. Two men are required to operate the machine. The cost of cutting and baling, including all items, is estimated at $2.40 per ton.

The value of the corn-stalks to the farmer for use on the farm is probably small. The immature stalks, together with grain, are used in the production of silage, which is an excellent food for farm animals. The mature stalks such as would be utilized commercially have very little food value. They are sometimes plowed under, where they have a doubtful value as a fertilizer. Immense quantities of stalks are burned annually in the corn belt in order to clear the ground for spring plowing.

About 20,000,000 tons of corn-cobs are produced each year in the United States. Practically their only use in the past has been as a low-grade fuel for domestic use. Like the corn-stalks the cobs have been the subject of extensive research by the chemical engineering department and Engineering Experiment Station. They have been destructively distilled, producing products similar to wood, as charcoal, acetic acid, formic acid, methanol, tar, illuminating gas and acetone. The charcoal has been shown to be an excellent feeding charcoal. After suitable treatment it forms an excellent decolorizing charcoal. As in the wood distillation industry the cobs are heated to a high temperature in a closed retort and the vapors condensed in suitable condensers.

It has been known for a long time that the pentosans, which are characteristic constituents of corn-cobs, could be utilized as a source of furfuraldehyde or, as it is commonly known, furfural. Extensive studies were carried on in the production of furfural from corn-cobs. The method worked out was to distill a mixture of dilute hydrochloric acid and ground corn-cobs. The vapor was condensed to a mixture of furfural and water which was fractionated to give almost pure furfural. Furfural, like formaldehyde, reacts to form a hard resin similar to bakelite. This resin may be used in production of certain varnishes, and, mixed with a suitable filler such as wood or corn-cob flour, as a molding resin. Instead of producing furfural from the cobs and then treating furfural with phenol, the plastic resin may be formed in the ground cobs by the addition of hydrochloric acid and phenol. The cellulose material of the cob remains in the resin, acting as a filler. The result is a low-grade plastic produced at a considerably lower cost than is possible by the other method. Furfural has excellent preservative properties, having been used in veterinary embalming fluid, in the antiseptic treating of seeds, and for other similar purposes. Furfural and some of its derivatives are excellent solvents for nitrocellulose and cellulose acetate. It is an excellent varnish remover. It was used in "dope" for airplane wings during the war. A number of dyes and anesthetics were prepared from furfural in the chemistry department of Iowa State College. Various furfural derivatives are excellent accelerators for use in the curing of rubber. Furfural can be used to replace gasoline, although

CHEMICAL ENGINEERING BUILDING, IOWA STATE COLLEGE



—Photo from the U. S. Bureau of Standards

COE ROLLER-TYPE DRIER USED FOR DRYING WALL-BOARDS
CHEMICAL ENGINEERING LABORATORY, IOWA STATE COLLEGE

at the present time it is too expensive for this purpose. Furfural, as a result of the extensive research on its production from various raw materials, is now made in large quantities at Cedar Rapids, Iowa, from oat hulls. While the yield from corn-cobs is greater, the oat hulls are used since they are segregated in great quantities as a waste product of the oatmeal industry. As a result of the large scale production the price of furfural has dropped in the last few years-from $30 to 15 cents per pound.

When corn-cobs are digested under pressure in water a strong adhesive can be produced. If dilute mineral acid is added a solution of xylose can be produced. Xylose is a sugar which up to the present time has been produced in large quantities only as a syrup. Since xylose has practically no food value it probably can be used by diabetic patients without the harmful effects produced by cane or beet sugar.

Oxalic acid has been produced in the laboratory by fusing corn-cobs with caustic soda and also by oxidizing corn-cobs with nitric acid. Considerable experimental work was done on the softening of water by using the impure corn-cob-alkali fusion mass direct without separating out the oxalic acid.

Various other uses have been found for corn-cobs. They have been ground to a flour which may be substituted for wood flour in many uses. It has been made into very good punk and incense. Ground cobs have been used in curing concrete floors in place of sawdust and have been substituted for bran for removing the oil from tin plate in the tin-plating industry. Corn-cobs have been used successfully in bee-smoking and in smoking of meats.

THE PROGRESS OF SCIENCE

FIFTY YEARS OF THE UNITED STATES GEOLOGICAL SURVEY

On March 21, 1929, the U. S. Geological Survey celebrated the fiftieth anniversary of the appointment of its first director. President Hoover, who at one time was a member of the organization, received the present members at the White House, and Mrs. Hoover, who was trained as a geologist, gave them a brief talk. In the afternoon, at a meeting held in the National Museum, Dr. Ray Lyman Wilbur, secretary of the interior; Dr. H. Foster Bain, secretary of the American Institute of Mining and Metallurgical Engineers; Dr. Arthur E. Morgan, president of Antioch College; Dr. Henry Fairfield Osborn, president of the American Museum of Natural History; Dr. Arthur L. Day, director of the Carnegie Geophysical Laboratory, and Dr. John C. Merriam, president of the Carnegie Institution of Washington, made appropriate addresses. In the evening nearly six hundred members and friends of the Geological Survey gathered at a banquet at the Washington Hotel.

At the afternoon meeting the development of the survey and its purposes, ideals and accomplishments were outlined by Dr. Bain, a summary of whose address THE SCIENTIFIC MONTHLY has been given the privilege of printing.

The U. S. Geological Survey was formed fifty years ago by the consolidation of four distinct organizations. These surveys, though each had an official title, have long been best known by the names of the men who directed them. Clarence King, John W. Powell, Geo. M. Wheeler and Ferdinand V. Hayden were true path breakers, and they left the impress of their personalities on their times and their country. King, who was made the first director of the new organization, was a mining engineer belonging to that group of brilliant engineers of foreign training who first in any large way brought science to the service of American mines. The Fortieth Parallel Survey, which he directed, worked in a definite field, from California to Colorado, and had a systematic plan of geologic and topographic mapping covering the whole area, followed by studies in structure and even in the technology of mining.

Major Powell, who later became the second director, was a many-sided man. A study of his work and reports gives the impression of a powerful mind avid for contacts in many directions. It was Powell and the men of his group, probably, who kept the Geological Survey from becoming merely a different type of mining bureau. Powell was interested in the lands, the forests and the waters, and in man's relations to all these, as well as to mines. It was the Powell influence which led the survey to foster studies of the Indians and resulted in the creation of the Bureau of American Ethnology. The same influence was responsible for the large part played by the survey in initiating the Forest Service and the Reclamation Service. Powell the explorer gave us the Grand Canyon, but he also gave us ideas; it would be appropriate to refer to him, for example, as the "Father of Physiography."

Wheeler was an engineer officer, and to him, apparently, we owe the plan for a complete topographic map with the system of quadrangle units. The geologic studies conducted by him were not systematic, like those of the King survey, but they were highly significant. One need only mention Gilbert and Russell, two members of the Geological Survey who came from the Wheeler organization, to indicate how great was its contribution to the fundamental problems of western geology.

The Hayden survey was in many ways the most characteristically scientific group of the four. The impress of the Philadelphia Academy of Natural Sciences was strong upon it, and it gave a powerful impulse to the study of paleontology and other scientific branches. Hayden gave us the Yellowstone and through that our great national park system, but he did even more. He gave us Holmes, Peale and Gannett—to name only three of the great leaders developed under his guidance.

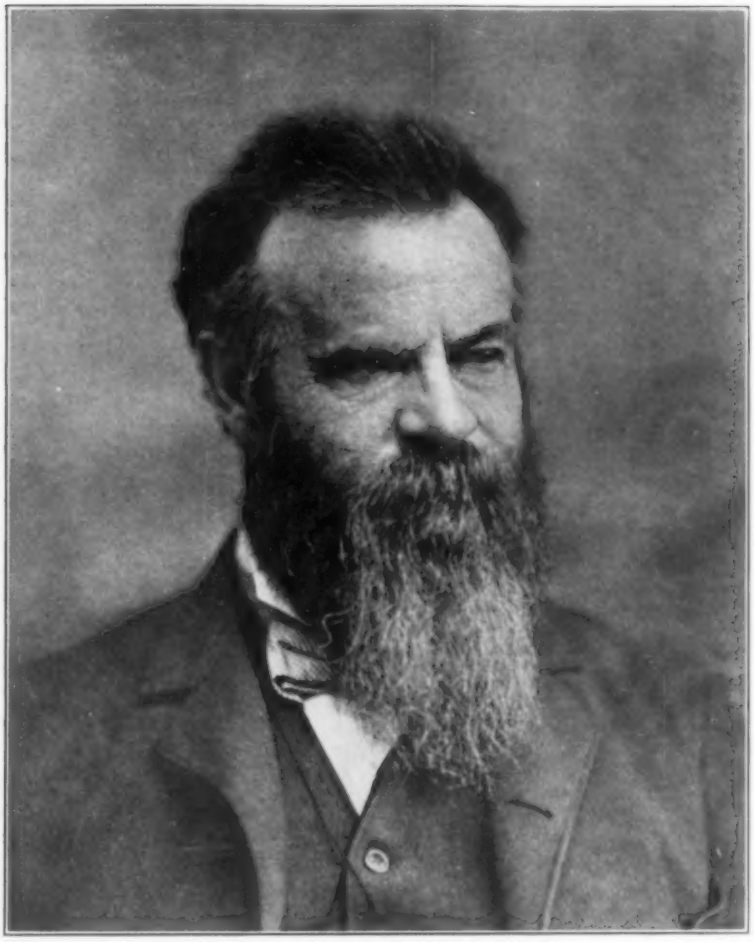
Such an assemblage of men and plans gave the new survey the ideals that have governed it for half a century. Beginning as a study of the public domain, it promptly became truly

CLARENCE KING

First Director of the United States Geological Survey.

national in scope. It was from the beginning scientific and systematic, but always with a most sympathetic attitude toward the problems of the engineer and the industrialist. Wisely it has elected to be the designer rather than the builder of the bridge over which industry functions. It has encouraged private enterprise, and with rare good sense has mothered new bureaus to carry out plans developed within its own organization rather than attempted unwieldy expansion.

No part of the field of geology has been neglected, and always leaders have been developed. King brought over Zirkel to apply the new art of microscopic petrography; Cross, Iddings and F. E. Wright kept up the succession. In the study of ore deposits King, Emmons, Hague and Becker formed the first great group, with occasional help from Pumpelly and such young men as Hammond and Hoover, who later became world famous. The second generation of students of ore genesis were equally able men. Lindgren, Spurr and Ransome, with the young men they trained, have set new standards in all parts of the world. In the Lake Superior region Irving, Van Hise and Leith have kept up the succession, and in petroleum geology the survey has almost created a new field, despite the credit properly to be given to others, especially I. C. White. Willard Hayes and the men associated



JOHN W. POWELL

SECOND DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY.

with him were truly founders. The great impulse toward systematic study of American coal fields came from the Second Geological Survey of Pennsylvania, but the U. S. Geological Survey advanced the work far beyond its old scope and refined and improved the methods. In this work M. R. Campbell introduced exactness, ultimately leading to structural contour maps; E. W. Parker established the tradition of economic study, and J. A. Holmes fathered the introduction of technology. G. O. Smith and F. G. Tryon keep the old tradition well alive, and that fruitful partnership, I am glad to note, survives the operation of transfer of one of the two men to another bureau.

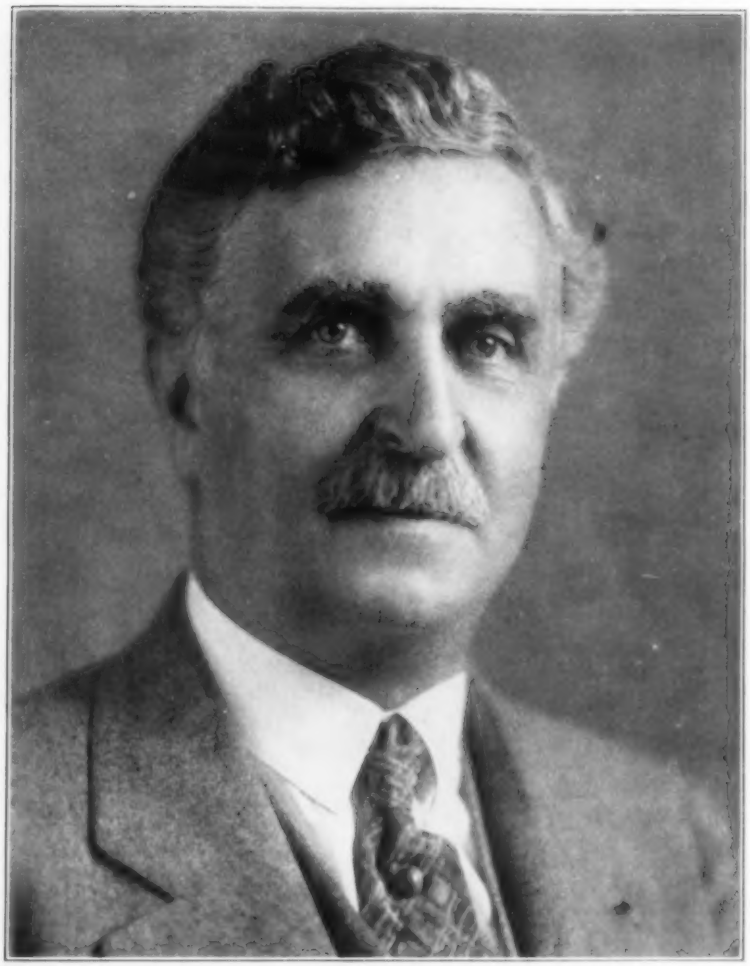
Preferring always to do well the work in its own field rather than to dissipate energy and resources, the survey has been mother to four separate bureaus and has played a large part in molding other organizations. The Bureau of American Ethnology, which was the first to be set off, has done work of lasting value in the study of our first Americans, and Powell, McGee and Holmes, three of its great leaders, were survey men. The Forest Service was formed around a survey division as a nucleus, and it is not too much to say that the early national forests were largely selected by survey men, just as Director Walcott guided the legislation creating them. For years, even after the Forest

CHARLES D. WALCOTT

THIRD DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY.

Service set up independent housekeeping, Henry Gannett was a power in its councils. The Reclamation Service grew directly out of the stream gaging and Powell's interest in arid lands. The first two directors, Newell and Davis, were survey men, and the topographic branch especially contributed heavily to its personnel. The Bureau of Mines grew out of a committee of survey members, later the technologic branch, and finally, in 1910, was set off to form a new bureau. All its directors except one have been former survey men. The broadening of the census into something more than a mere counting of noses began with the tenth census, in which survey men took a prominent part. The Federal Power Commission even now depends on the survey for much of its staff work. The Geophysical Laboratory of the Carnegie Institution was a direct outgrowth of the old physics section of the survey, and Director Walcott had a large share in organizing it.

So, wherever we turn, in science, engineering or industry, we see the fructifying influence of the survey. Perhaps its greatest contribution is one not often realized—the large part it has played in teaching the public the fundamental importance of minerals to our civilization and the need of molding legislation and practice toward their wise use and conservation. Throughout its fifty years of service it has con-



DR. O. S. SMITH

PRESENT DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY.

stituted a day-by-day example of the possibility of applying service in industry to the benefit of the nation and the people.

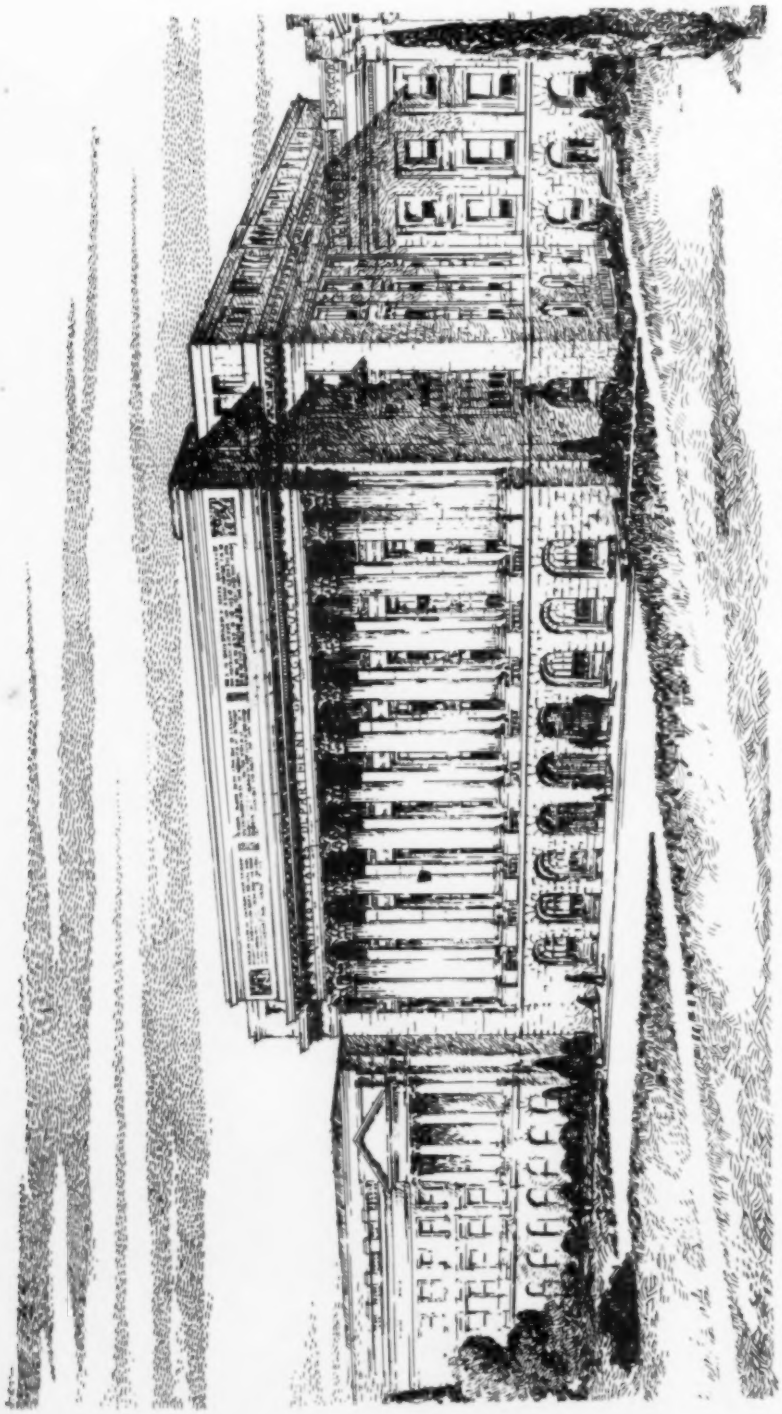
The appropriations for the work of the survey have increased from $100,000 for the fiscal year 1880 to over $2,000,000 for the fiscal year 1930. The total expenditures during the life of the survey have been about $75,000,000, including nearly $10,000,000 of state cooperative funds. The published reports by which the Geological Survey's work are made available aggregate over 400,000 pages and occupy 120 feet of shelf space. Other organizations which are in a real sense children of the Geological Survey, their work having been started by the survey, include the Bureau of Reclamation, the Bureau of Mines, the Bureau of American Ethnology, the Forest Service and the Geophysical Laboratory of the Carnegie Institution.

THE JOHN FRITZ GOLD MEDAL

To be presented to President Herbert Hoover during the last week in April. The medal is awarded annually for notable scientific or industrial achievement by the four national engineering societies: the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers. The medal was awarded to Mr. Hoover in October, 1928, the decision having been made more than a year before his election to the presidency.

PRESIDENT HERBERT HOOVER

A PHOTOGRAPH TAKEN IN THE FALL OF 1928.



ARCHITECT'S DRAWING OF THE NEW BUILDING OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

THE NEW AGRICULTURAL BUILDING AT WASHINGTON

THIS is the architect's drawing of the new administration building of the Department of Agriculture in Washington, connecting the east and west wings, which are now standing and occupied. The building will be located on the Mall, just east of the Washington Monument. It will have an impressive entrance lobby and staircase. In the interior finish of the lobby several different kinds of marble will be used. The base of the building will be of granite and the superstructure and Corinthian columns of marble. The main five-story part will inclose a court, which will be paved, on a level three steps below the general level of the ground floor, and will be glassed over on a level with the second floor. The court will be devoted to decorative purposes, not being intended for offices of any kind. This picture is of the main façade, facing on the Mall, looking north on Thirteenth Street beyond the Mall. The offices of the secretary of agriculture will occupy the second floor front, just behind the columns. The rest of the unit will be occupied by the offices of the assistant secretary, the various directors and other administrative officers. A feature of special interest on the façade is the entablature, the long panel resting upon the capitals of the columns. On this entablature will be engraved inscriptions appropriate to the nature of the purpose for which the building will exist. The total amount authorized for the construction of the central part shown above is $2,000,000. The design shown was produced by Rankin and Kellogg, architects, of Philadelphia, and approved by James A. Wetmore, acting supervising architect of the Treasury Department.

At this time the steel frame and floors are completed and the setting of the exterior marble has reached nearly to the second floor. The completed structure, including the east and west wings and the connecting building shown at the left, will have a frontage of 750 feet. In the accompanying picture part of the east wing is shown, the west wing, lying to the right of the new building, not appearing in the architect's drawing.

In addition to the administration building, which will connect the two existing wings constructed some years ago, the government building program includes the erection for Department of Agriculture activities of a very large building, of an extensible type, on three squares of ground which are now being acquired by the government just to the south of the location of the administration building. At present the offices and laboratories of the Department of Agriculture in Washington are scattered in more than forty buildings in different parts of the city. The erection of the new buildings will bring these scattered activities together and this will not only greatly simplify the work but will prove a tremendous convenience to the many visitors to the department, who now find it very difficult to locate just the office with which they desire to transact business. The department has grown tremendously during recent years. Its employees in Washington now number about six thousand, with sixteen thousand more outside of Washington. Its activities include not only the service to farmers all over the country but also the Weather Bureau, the Forest Service, the Bureau of Public Roads, the Bureau of Home Economics, and the enforcement of laws, such as the pure food law, the meat inspection law and many others which directly affect the health and welfare of the general public.

Dass die Gleichungen (12) in erster Näherung die Gravitationsgleichungen enthalten, die Gleichungen (11) die (in Verbindung mit der Existenz eines Potential-Vektor) die Maxwell'schen Gleichungen für das Vakuum, ist schon gesagt worden. Es habe auch gezeigt können, dass umgekehrt zu jedem [illegible] dieser Gleichungen ein Feld existirt* [illegible]. Durch Verjüngung der Gleichungen (10) erhält man eine Bedingung für das elektrische Potential

$$\left.\begin{aligned} f^{\ell}_{,\ell} - \tfrac{1}{2}\, \mathfrak{H}^{\sigma}_{\underline{\kappa\tau}}\, \Lambda^{\kappa}_{\sigma\tau} &= 0 \\ (2f^{\ell} = \mathfrak{H}^{\alpha}_{\alpha\underline{\ell}} &= 2h\varphi^{\ell}) \end{aligned}\right\} \ldots\ldots (10a)$$

Eine tiefere Untersuchung der Konsequenzen der Feldgleichungen (11), (10a) wird zu zeigen haben, ob die Riemann-Metrik in Verbindung mit dem Fern-Parallelismus wirklich eine adäquate Auffassung der physikalischen Qualitäten des Raumes liefert. Nach dieser Untersuchung ist es nicht unwahrscheinlich. — Albert Einstein I 1929.

* Dies alles nur, soweit es sich um die linearen Gleichungen der ersten Approximation handelt.

FACSIMILE REPRODUCTION OF A PORTION OF PROFESSOR EINSTEIN'S MANUSCRIPT

THE LOWER HALF OF PAGE 7 OF PROFESSOR ALBERT EINSTEIN'S ORIGINAL MANUSCRIPT BEARING THE TITLE "ZUR EINHEITLICHEN FELDTHEORIE." THE COMPLETE MANUSCRIPT IN DR. EINSTEIN'S HANDWRITING HAS BEEN PRESENTED TO THE OLIN LIBRARY OF WESLEYAN UNIVERSITY.